Digital Economy and Society Index (DESI) 2021

Digital infrastructures

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1 Digital infrastructures

1.1 Broadband connectivity

The Digital Decade defines two targets in the area of broadband connectivity for 2030: gigabit coverage for all households and 5G in all populated areas.

The connectivity dimension of the Digital Economy and Society Index (DESI) looks at both the demand and the supply side of fixed and mobile broadband. Under fixed broadband, it assesses the take-up of overall, at least 100 Mbps and at least 1 Gbps broadband, the availability of fast broadband (next generation access of at least 30 Mbps) and of fixed very high capacity networks (VHCNs)[1]. Under mobile broadband, it includes the population coverage of 4G and 5G[2] networks, the assignment of radio spectrum for 5G (5G readiness) as well as the take-up of mobile broadband[3]. In addition, it captures the retail prices of fixed and mobile offers and also those of converged bundles (consisting of fixed and mobile service components).

Table 1 Connectivity indicators in DESI

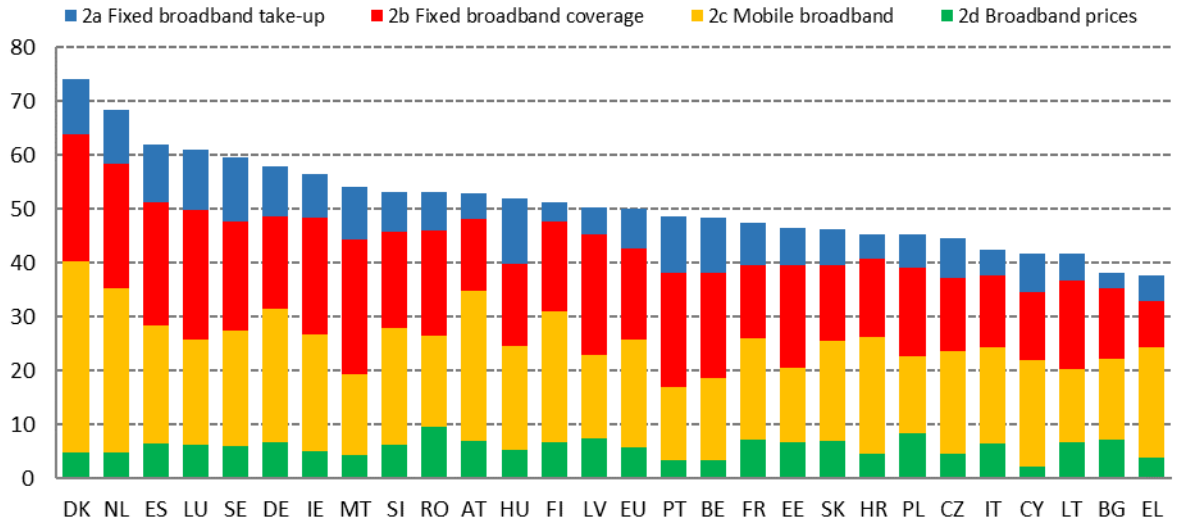
	EU	
	DESI 2019	**DESI 2021**
2a1 Overall fixed broadband take-up % households	**74%** 2018	**77%** 2020
2a2 At least 100 Mbps fixed broadband take-up % households	**21%** 2018	**34%** 2020
2a3 At least 1 Gbps take-up % households	**NA**	**1.3%** 2020
2b1 Fast broadband (NGA) coverage % households	**80%** 2018	**87%** 2020
2b2 Fixed Very High Capacity Network (VHCN) coverage % households	**33%** 2018	**59%** 2020
2c1 4G coverage % populated areas	**98.8%** 2018	**99.7%** 2020
2c2 5G readiness Assigned spectrum as a % of total harmonised 5G spectrum	**15%** 2019	**51%** 2021
2c3 5G coverage % populated areas	**NA**	**14%** 2020
2c4 Mobile broadband take-up % individuals	**65%** 2018	**71%** 2019
2d1 Broadband price index Score (0-100)	**NA**	**69** 2020

Source: DESI 2021, European Commission.

In connectivity, Denmark has the highest score, followed by the Netherlands and Spain. Greece and Bulgaria has the weakest performance on this dimension of the DESI.

[1] Fixed VHCN coverage refers to the combined coverage of FTTP and DOCSIS 3.1 cable networks.
[2] 5G coverage was introduced in DESI in 2021.
[3] The mobile broadband take-up indicator has been revised, see the DESI methodological note for further details.

Figure 1 Digital Economy and Society Index 2021, Connectivity



Source: DESI 2021, European Commission.

As for the mobile broadband sub-dimension (including indicators 2c1, 2c2, 2c3 and 2c4, indicated in yellow in the above chart), the Netherlands, Denmark and Austria lead Europe, while Portugal and Lithuania registered the lowest scores.

1.1.1 Broadband coverage

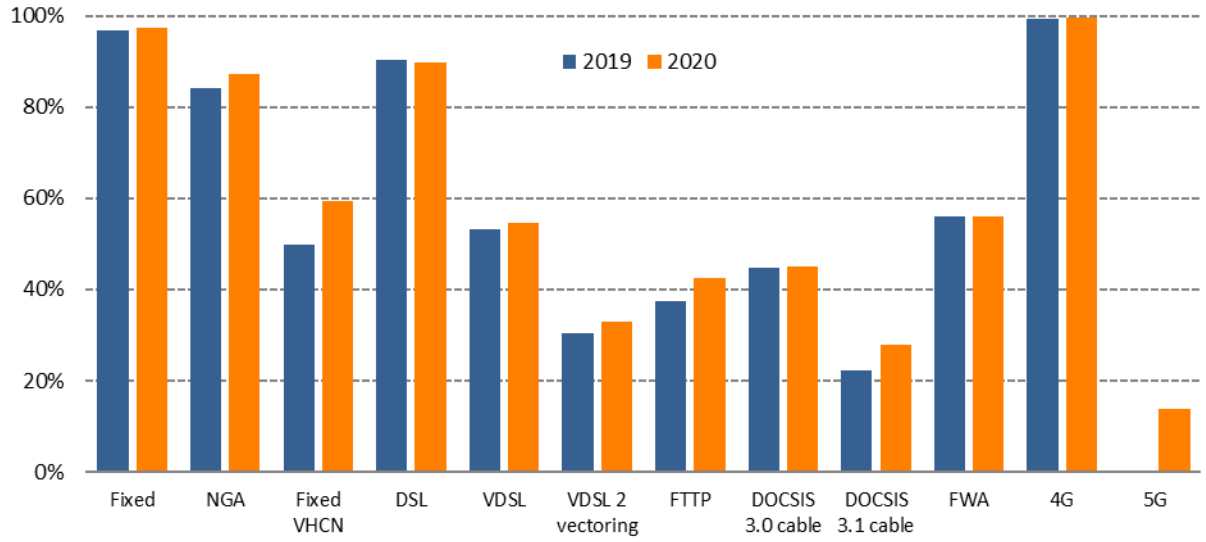
At least one basic broadband network has been available to all households in the EU since 2013, when considering all major technologies (xDSL, cable, fibre to the premises - FTTP, Fixed wireless access - FWA, 4G and satellite). Internet access at home is provided mainly through fixed technologies, the coverage of which remained stable at 97%. Among these technologies, xDSL continued to have the largest footprint (90%) followed by FWA (56%), DOCSIS 3.0 cable (45%) and FTTP (42%).

Coverage of Next generation access (NGA) technologies (VDSL, VDSL2 vectoring, FTTP, DOCSIS 3.0, DOCSIS 3.1) capable of delivering download speeds of at least 30 Mbps reached 87% in 2020, following a slight increase of 3.1 percentage points compared to the previous year. This mainly resulted from a 5-point growth in FTTP. VDSL coverage went up by 1.5 percentage points, while cable DOCSIS 3.0 remained unchanged at 45%.

Fixed very high capacity networks (VHCN), having the capabilities of offering gigabit connectivity, covered 59% of EU homes in 2020, up from 50% a year earlier. FTTP deployments and cable network upgrades to DOCSIS 3.1 (coverage went up from 22% to 28%) were equally important in growing VHCN coverage in 2020.

Regarding mobile technologies, while 4G is almost universal reaching 99.7% of populated areas, 5G commercial services were launched in about half of the member states by mid-2020 covering 14% of populated areas.

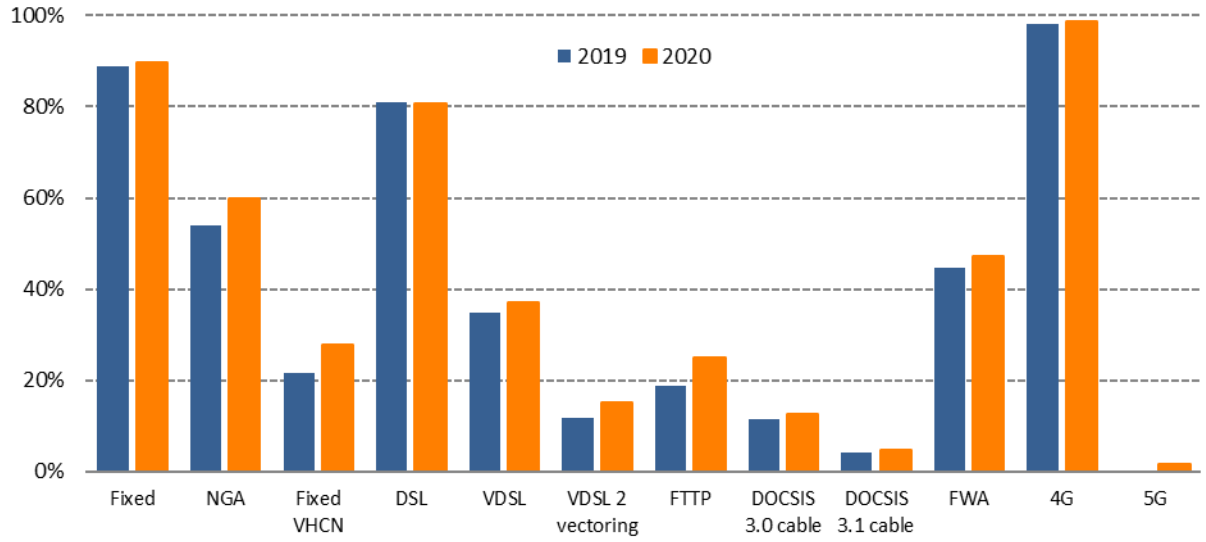
Figure 2 Total coverage by technology at EU level (% of households), 2019-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

Broadband coverage of rural areas[4] remains challenging, as 10% of households are not covered by any fixed network, and 40% are not served by any NGA technology. Nevertheless, 4G is widely available also in rural areas (98.6%). Regarding fixed technologies, there was a marked increase in the rural coverage of FTTP (from 19% in 2019 to 25% in 2020).

Figure 3 Rural coverage by technology at EU level (% of households), 2019 – 2020

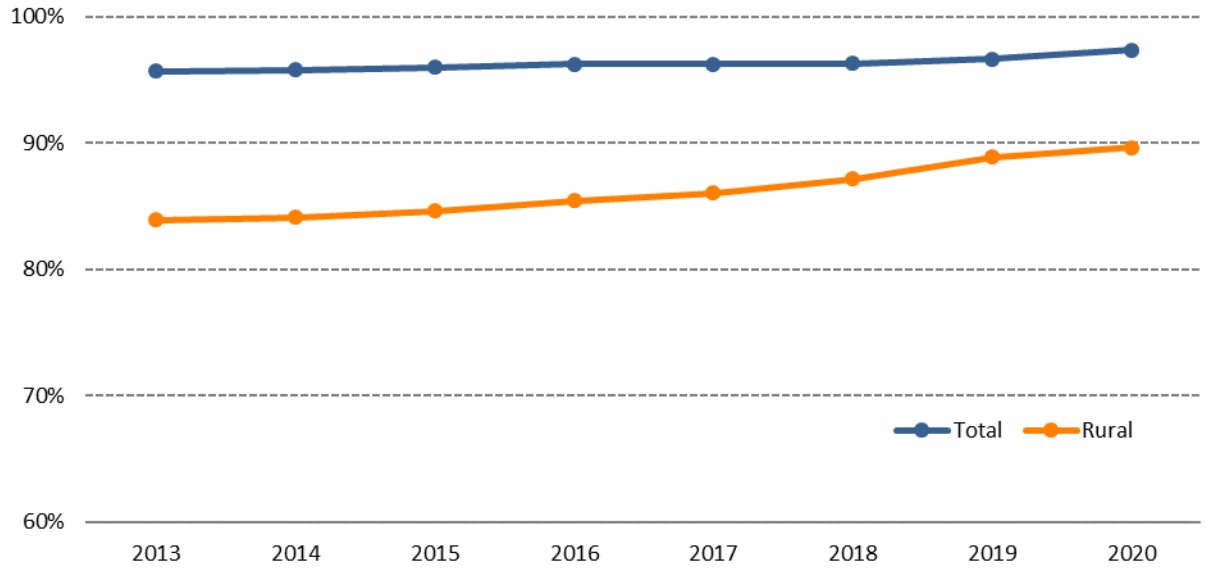


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

Overall coverage of fixed broadband has only marginally increased since 2013 from 95.7% to 97.4%. Rural coverage improved from 83.9% in 2013 to 89.7% in 2020.

[4] For the definition of rural areas see sub-chapter "3.2 Defining households and rural areas" in the methodology of the study "Broadband Coverage in Europe 2018", page 16, by IHS Markit and Point Topic (https://ec.europa.eu/digital-single-market/en/news/study-broadband-coverage-europe-2018).

Figure 4 Fixed broadband coverage in the EU (% of households), 2013 - 2020

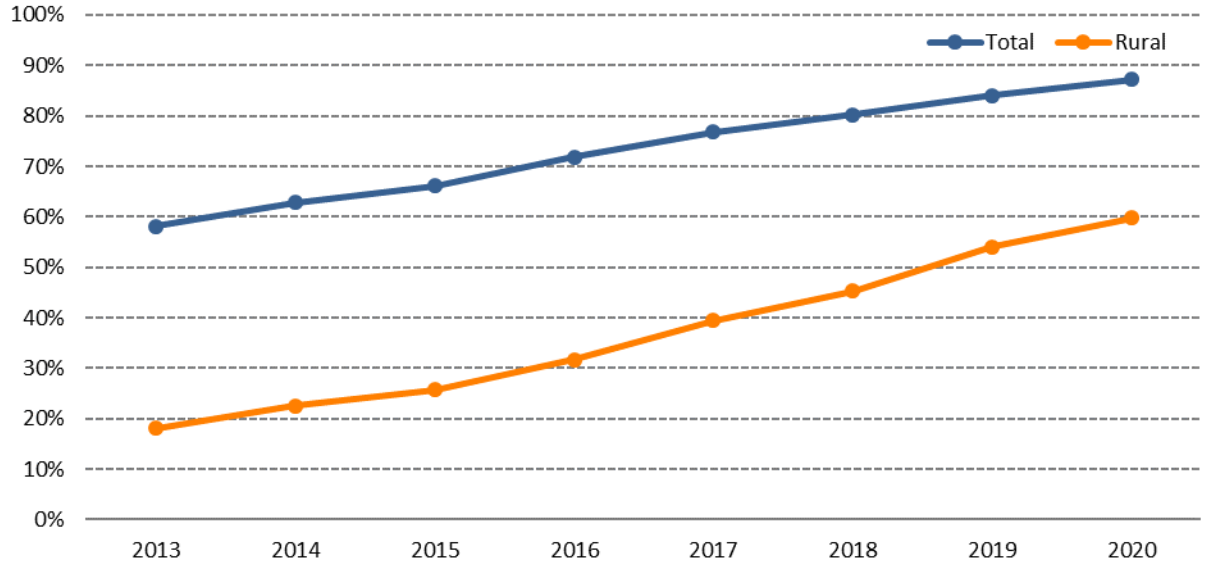


Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

Fixed coverage is close to universal in the majority of the EU with less than 3% uncovered households in 19 Member States. On the other hand, Lithuania, Poland and Romania are lagging behind with less than 90% of households covered.

NGA is available in the vast majority of EU homes (87%), but only 60% can benefit from such services in rural areas. VDSL has the largest coverage among NGA technologies (55%), followed by cable (45%) and FTTP (42%).

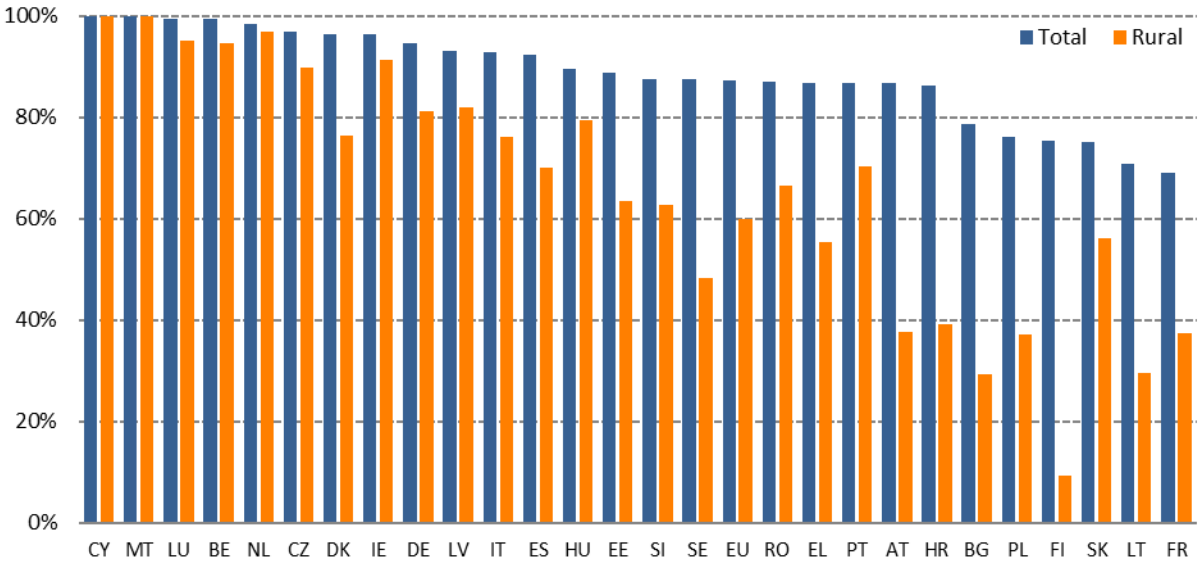
Figure 5 Next generation access (NGA) broadband coverage in the EU (% of households), 2013-2020



Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

In Cyprus, Malta, Luxembourg and Belgium, NGA is available in more than 99% of households. The situation remained challenging in France (69%) and Lithuania (71%), despite the fact that both countries improved in 2020 (France by 7 and Lithuania by 2 percentage points).

Figure 6 Next generation access (NGA) broadband coverage in the EU (% of households), mid-2020

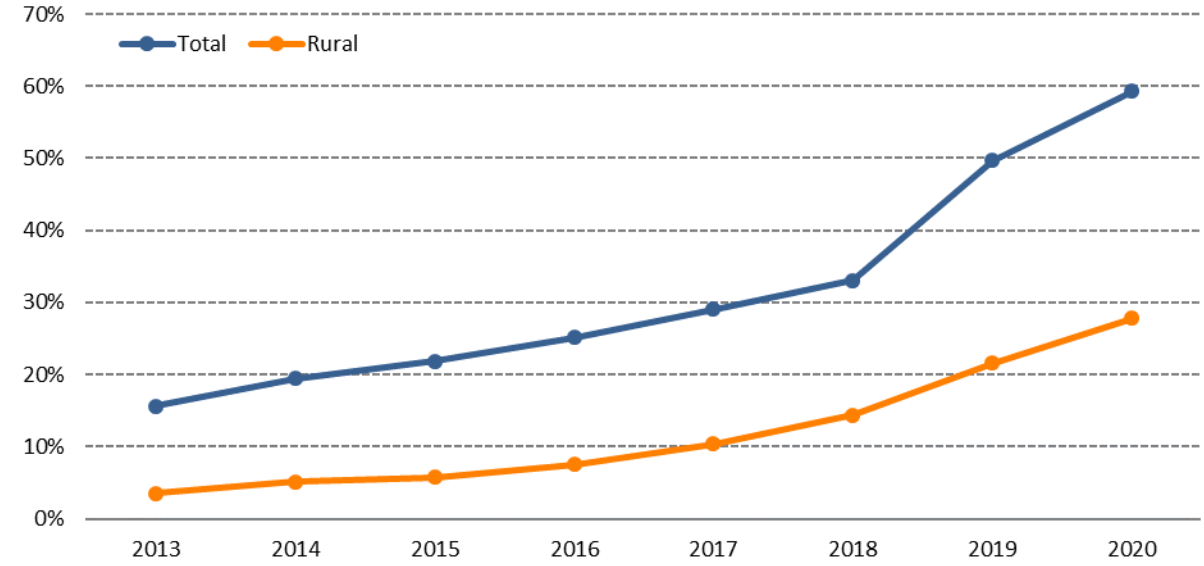


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

VHCN coverage increased significantly between 2013 and 2020 from 16% to 59%. Coverage almost doubled in the last two years, as the upgrade of cable networks to DOCSIS 3.1 started in several Member States and FTTP deployments also accelerated.

In rural areas, growth was lower, but still substantial, from 4% to 28% over the same time period. The large gap between total and rural VHCN coverage shows the regional disparities in digital opportunities and confirms that more investment is needed in rural areas in order to catch up.

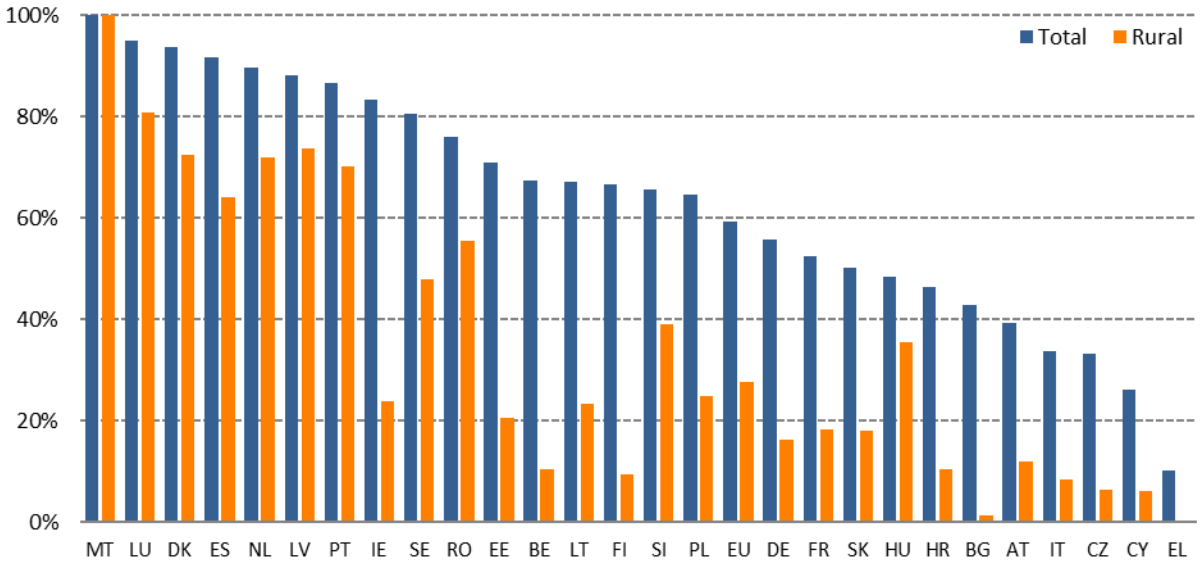
Figure 7 Fixed very high capacity network (VHCN) coverage (% of households) in the EU, 2013-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

In mid-202, Malta was leading with 100% of VHCN coverage, followed by Luxembourg, Denmark and Spain with above 90% coverage. The poorest performers were Greece (10%), Cyprus (26%) and Czechia (33%), although they all improved in 2020. There has been spectacular progress in Ireland (48 percentage points), Austria (25 percentage points) and Germany (23 percentage points).

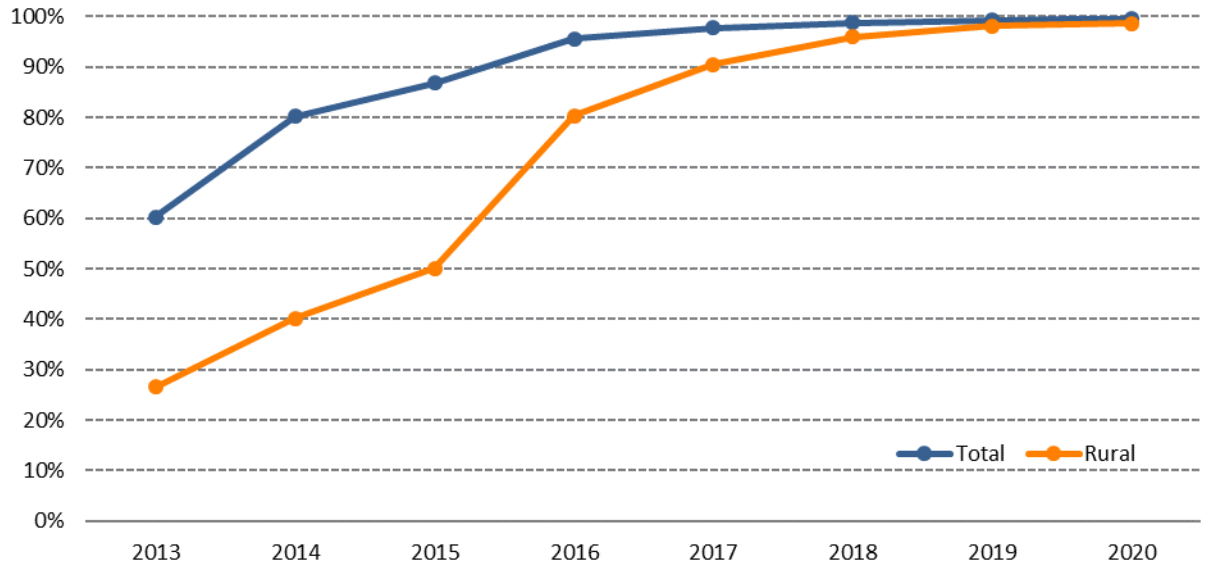
Figure 8 Fixed very high capacity network (VHCN) coverage (% of households), mid-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

4G (LTE) is almost ubiquitous with 99.7% of populated areas covered by at least one operator in the EU, being even more widely available than fixed broadband (97.4%). In the last three years, the gap between rural and overall 4G coverage almost closed. Rural coverage stood at 98.6% in 2020.

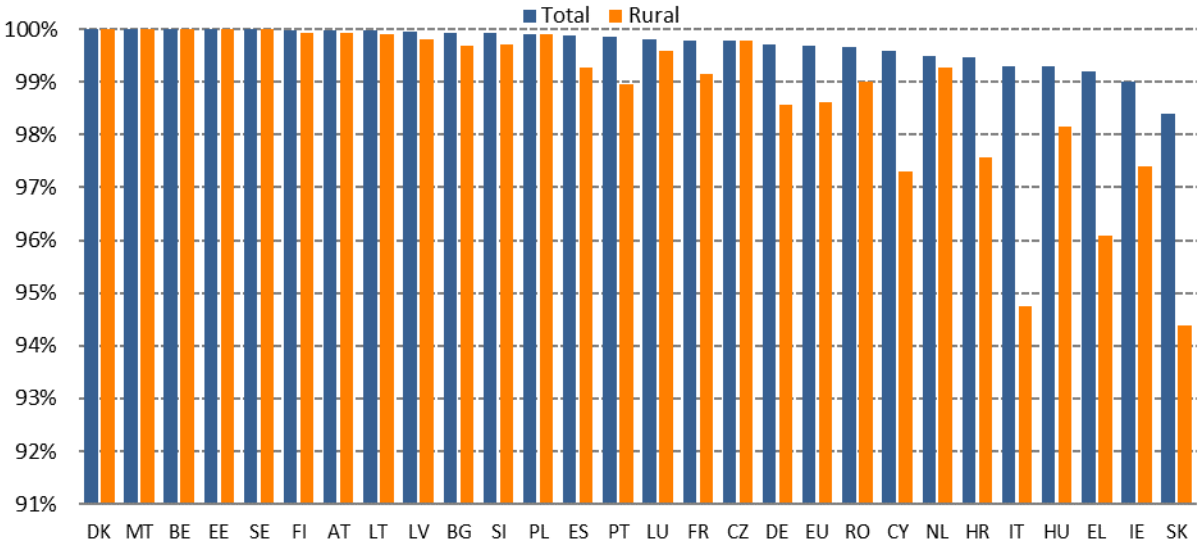
Figure 9 4G mobile coverage in the EU (% of households), 2013-2020



Source: IHS Markit, Omdia, Point Topic and VVA, Broadband coverage in Europe studies.

All Member States have well above 95% coverage of 4G.

Figure 10 4G mobile coverage (% of populated areas), mid-2020



Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

The 5G readiness indicator in the DESI shows the portion of spectrum assigned for 5G purposes in each Member State in the 5G pioneer bands. The percentage score of the 5G readiness indicator is based on the amount of spectrum assigned in a specific Member State and ready for 5G use by the end of 2020 within the 5G pioneer bands identified in Europe.

This score is calculated based on the portion of spectrum assigned in each 5G pioneer band in comparison with the maximum feasible amounts, which are as follows:

- 700 MHz band: 60 MHz (703-733 & 758-788 MHz),
- 3.6 GHz band: 400 MHz (3,400-3,800 MHz),
- 26 GHz band: 1000 MHz within 24,250-27,500 MHz.

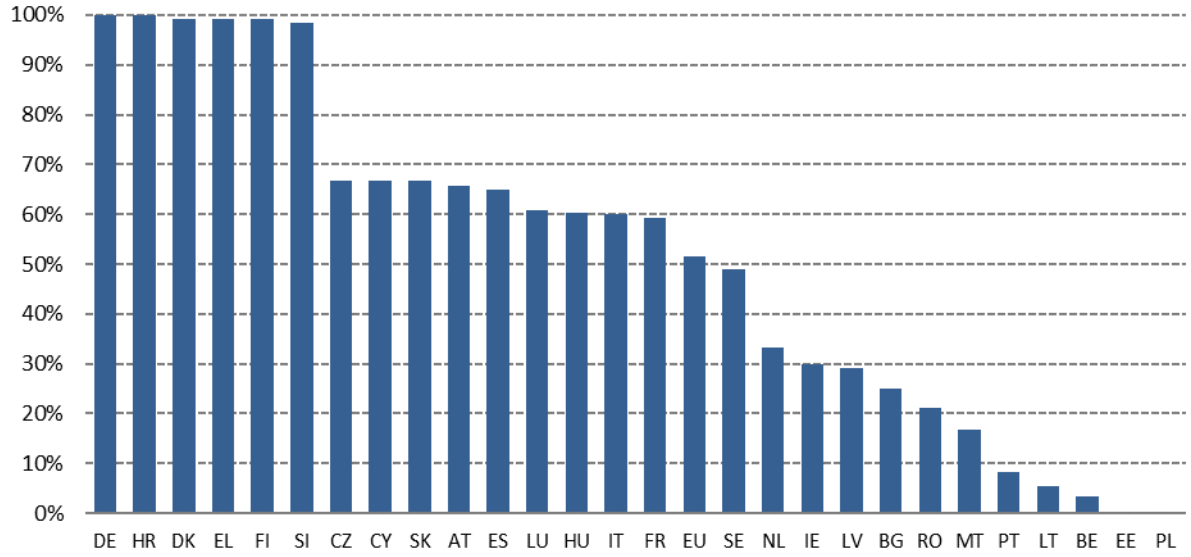
All three spectrum bands have an equal weight, so having the maximum feasible amount assigned – and ready for 5G use – in the range of one of these bands will result in a score of 33.3%, i.e. one third of the total maximum score.

Remarks:

1. For the 700 MHz band, there are a number of derogations allowing for a delay until 2022; however, the 5G readiness indicator is about factual reporting, not a judgement on legal compliance.
2. For the 3,400-3,800 MHz band, only licences aligned with the latest technical conditions (in accordance with Commission Implementing Decision (EU) 2019/235) were considered ready for 5G use.
3. For the 26 GHz band, at least a portion of 1,000 MHz within the band must be assigned and ready for 5G use by the end of 2020, as required by the European Electronic Communications Code.

By the end of August in 2021, 25 of the 27 Member States had assigned spectrum in the 5G pioneer bands, compared to 16 a year earlier. Germany, Croatia, Denmark, Greece, Finland and Slovenia assigned more than 90% of spectrum. On the other hand, Estonia and Poland have not yet assigned any 5G spectrum (according to the above conditions).

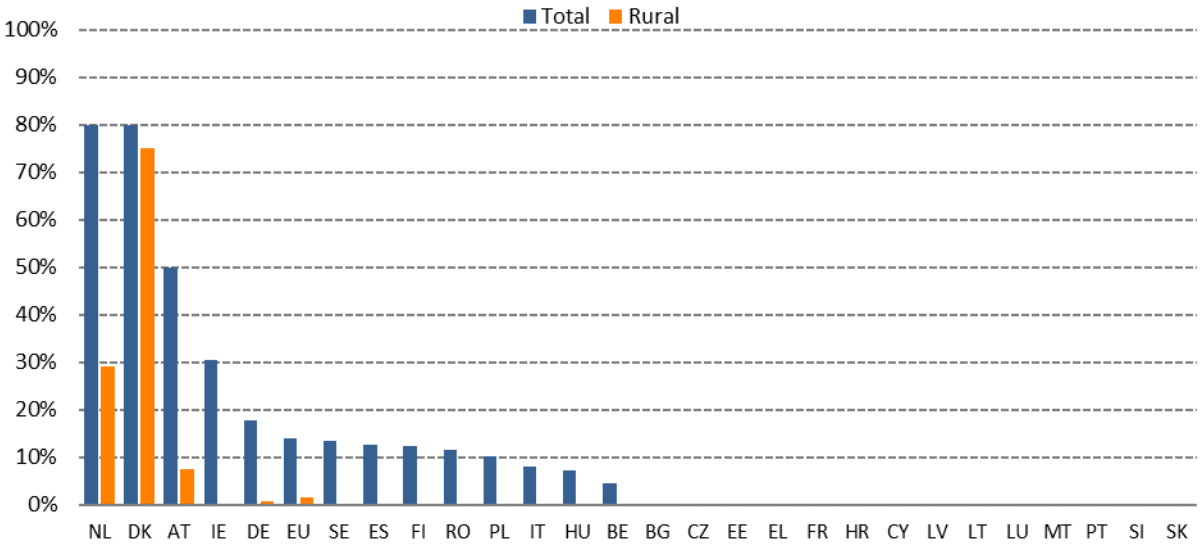
Figure 11 5G readiness (assigned spectrum as a % of total harmonised 5G spectrum), end of August, 2021



Source: Communications Committee (COCOM) based on iDATE.

Following the spectrum assignments, 13 Member States started commercial 5G network deployments by mid-2020. Highest coverage levels were recorded in the Netherlands and Denmark (80% of populated areas each), followed by Austria (50%), Ireland (30%) and Germany (18%).

Figure 12 5G mobile coverage (% of populated areas), mid-2020

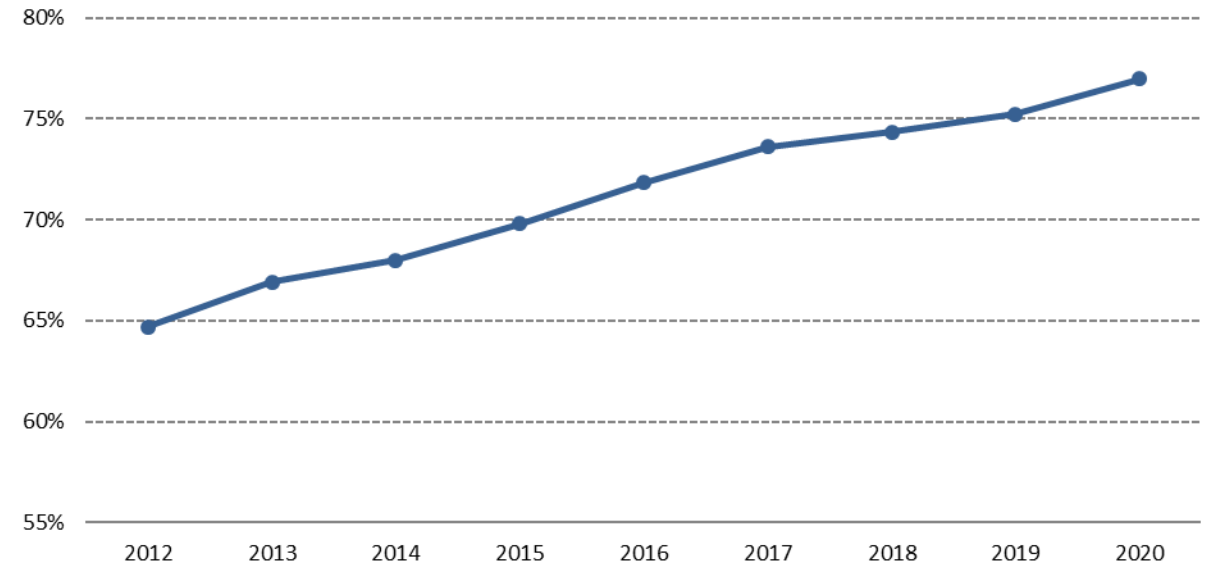


Source: IHS Markit, Omdia and Point Topic, Broadband coverage in Europe studies.

1.1.2 Fixed broadband take-up

Over three quarter of EU households (77%) had a fixed broadband subscription in 2020, following a steady growth (an annual growth rate of 2.1%) over the last 8 years.

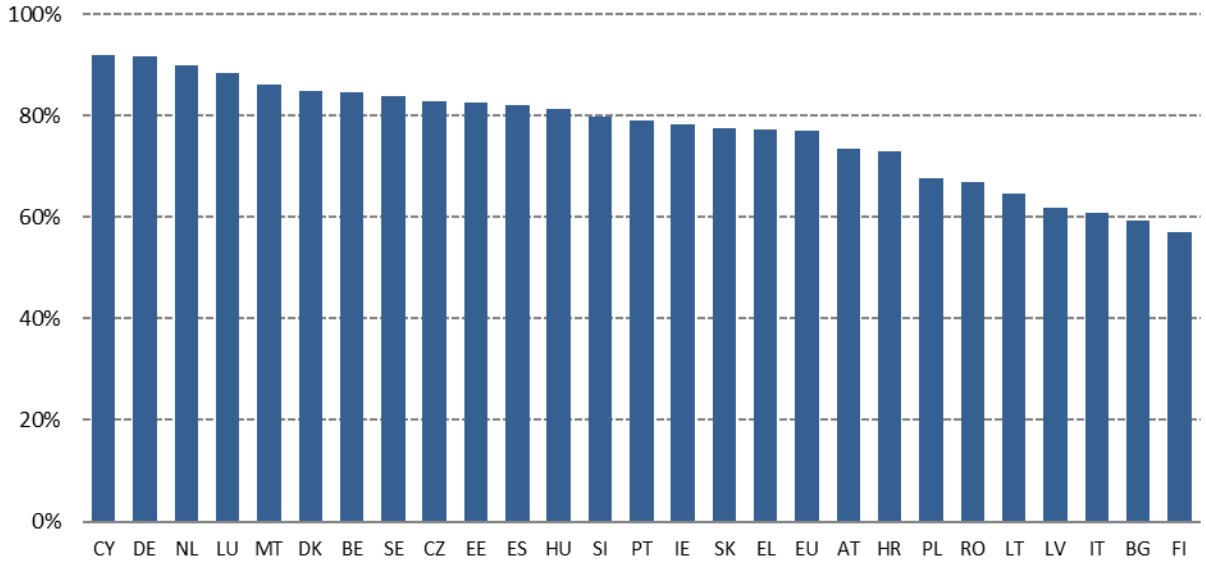
Figure 13 Households with a fixed broadband subscription in the EU (% of households), 2012-2020



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

National take-up rates ranged from only 57% to 92%. Cyprus, Germany and the Netherlands registered the highest figure, while Finland, Bulgaria, Italy, Latvia and Lithuania the lowest. The relatively low take-up rates in Finland, Italy, Poland and Latvia may partly be due to fixed-mobile substitution.

Figure 14 Households with a fixed broadband subscription (% of households), 2020

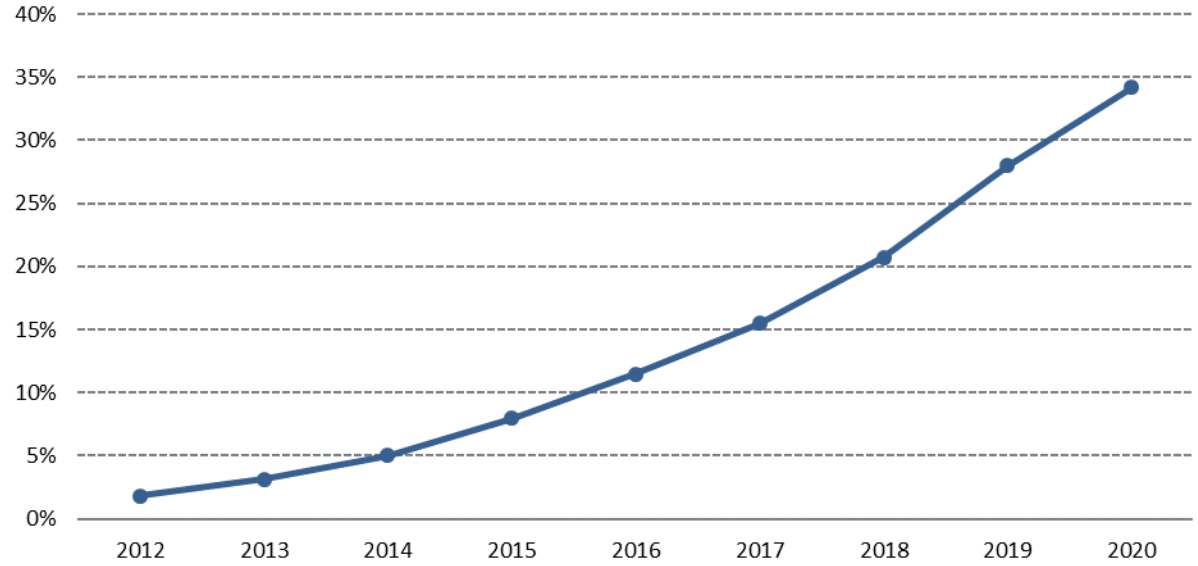


Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Similarly to broadband coverage, there is still a large difference between urban and rural figures. Only 69% of rural homes has a fixed broadband subscription compared with 81% in urban areas. The rural-urban gap is the largest in Bulgaria (40% vs. 72%), Finland (42% vs. 70%) and Romania (54% vs. 81%).

Looking at broadband speeds, there has been a sharp upward trend in at least 100 Mbps fixed broadband penetration since 2012. In 2020, more than one third of EU households subscribed to such a service (34%), up from 2% eight years ago.

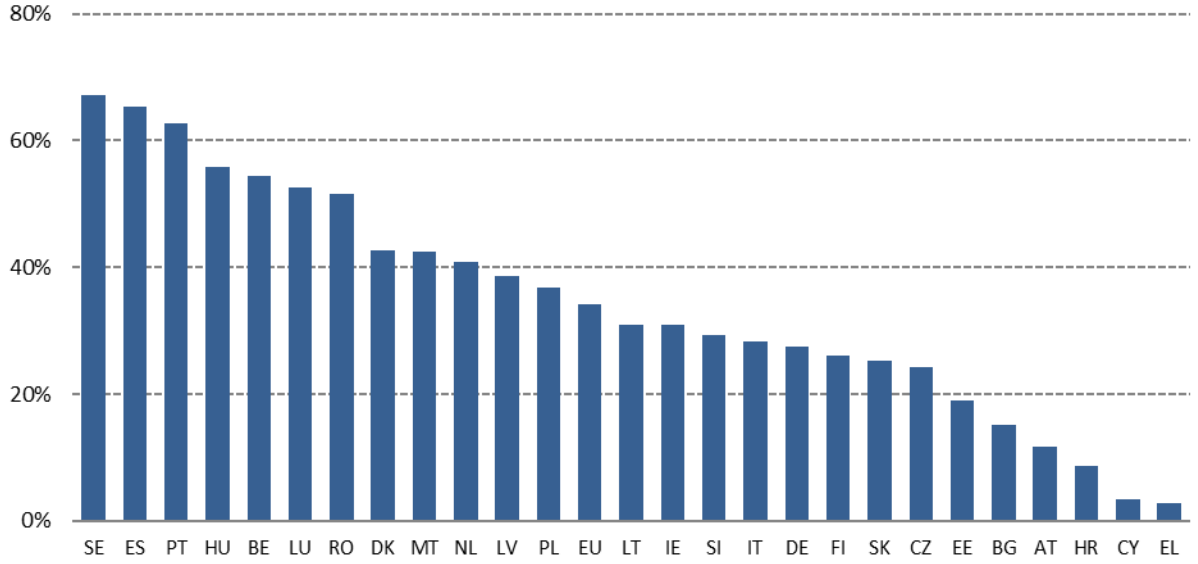
Figure 15 Households with a fixed broadband subscription of at least 100 Mbps (% of households) 2012 – 2020



Source: Estimated based on the European Union survey on ICT usage in Households and by Individuals and data from the Communications Committee (COCOM).

Sweden, Spain, Portugal, Hungary, Belgium, Luxembourg and Romania lead on this indicator with over 50% of households subscribing to at least 100 Mbps. In Greece, Cyprus and Croatia, by contrast, take-up is very low (less than 10%).

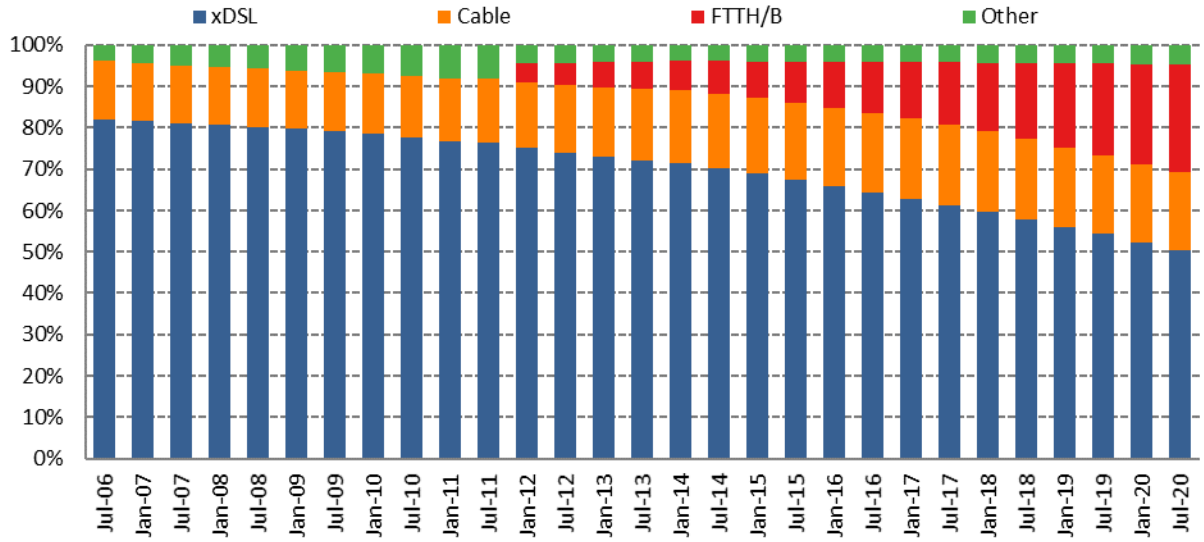
Figure 16 Households with a fixed broadband subscription of at least 100 Mbps (% of households), 2020



Source Estimated based on the European Union survey on ICT usage in Households and by Individuals and data from the Communications Committee (COCOM).

xDSL remained the most widely used fixed broadband technology, although its market share decreased to 50% in 2020 from 82% in 2006. Fibre to the home/building (FTTH/B) became DSL's main challenger over the last years: the share of FTTB/H lines increased from 5% in 2012 to 26% in 2020. Cable lines represented 19% of fixed broadband lines in 2020, compared with 14% in 2006.

Figure 17 Fixed broadband subscriptions – technology market shares in the EU (% of subscriptions), July 2006-July 2020[5]



Source: Communications Committee (COCOM).

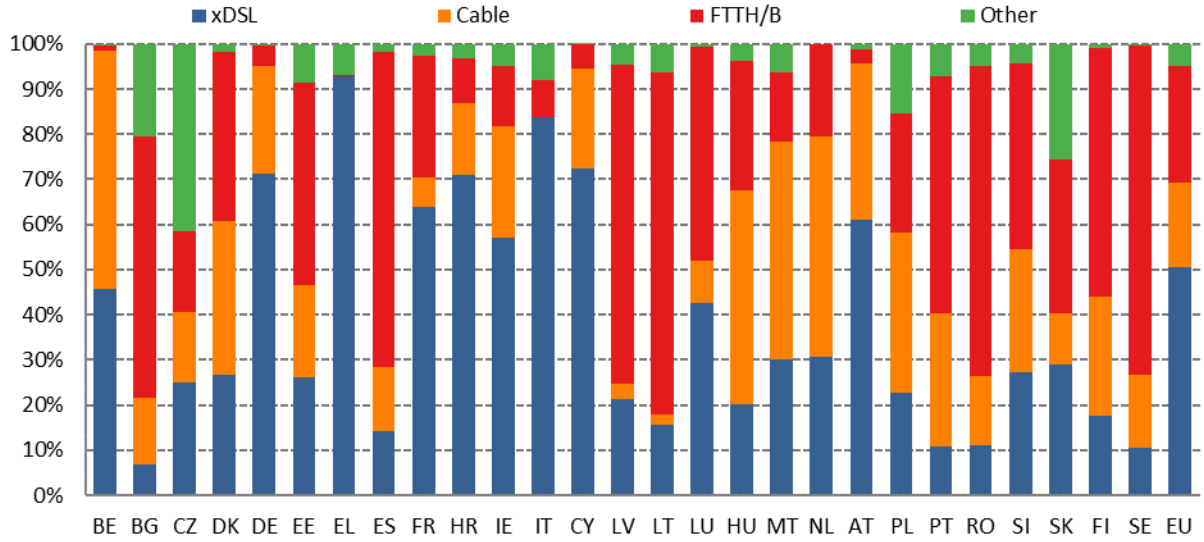
The market share of xDSL varies from 7% to 93% and is generally lower in Eastern Europe, where FTTH/B is more widely used. Cable is present in all but two Member States (Greece and Italy).

xDSL is particularly prevalent in Greece and Italy, and have the lowest market share in Bulgaria, Romania, Portugal, Sweden and Spain.

FTTH/B is the most widely used technology in a growing number of Member States, and has the highest market share in Lithuania, Sweden, Latvia, Spain and Romania.

On the other hand, cable is dominant in Belgium, the Netherlands, Malta and Hungary.

Figure 18 Fixed broadband subscriptions – technology market shares in the EU (% of subscriptions), July 2020



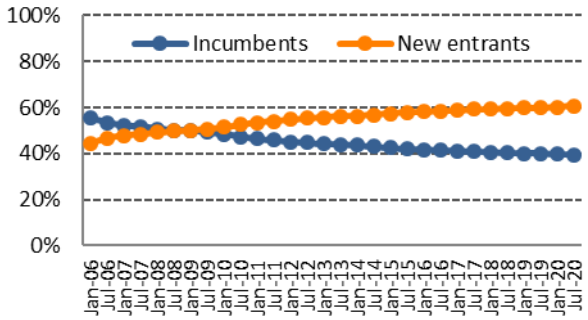
Source: Communications Committee (COCOM).

[5] FTTH/B is part of 'other' technologies until June 2011 on the chart.

New entrant operators continued to slightly gain market share and held 61% of fixed lines in 2020 compared with 45% in 2006. The market share of incumbents is the highest in Luxembourg (63%), Cyprus (55%), Latvia (55%) and Austria (54%), and the lowest in Romania (17%) and Czechia (22%).

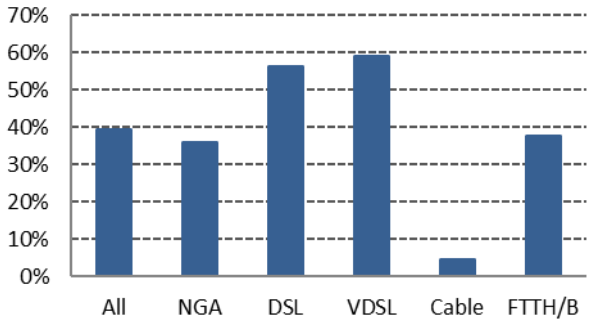
Market shares are calculated at national level for incumbents and new entrants. However, broadband markets are geographically fragmented, suggesting that a large number of households are served by only one provider (most likely the incumbent operator in this case).

Figure 19 Fixed broadband subscriptions – operator market shares in the EU (% of subscriptions), January 2006-July 2020



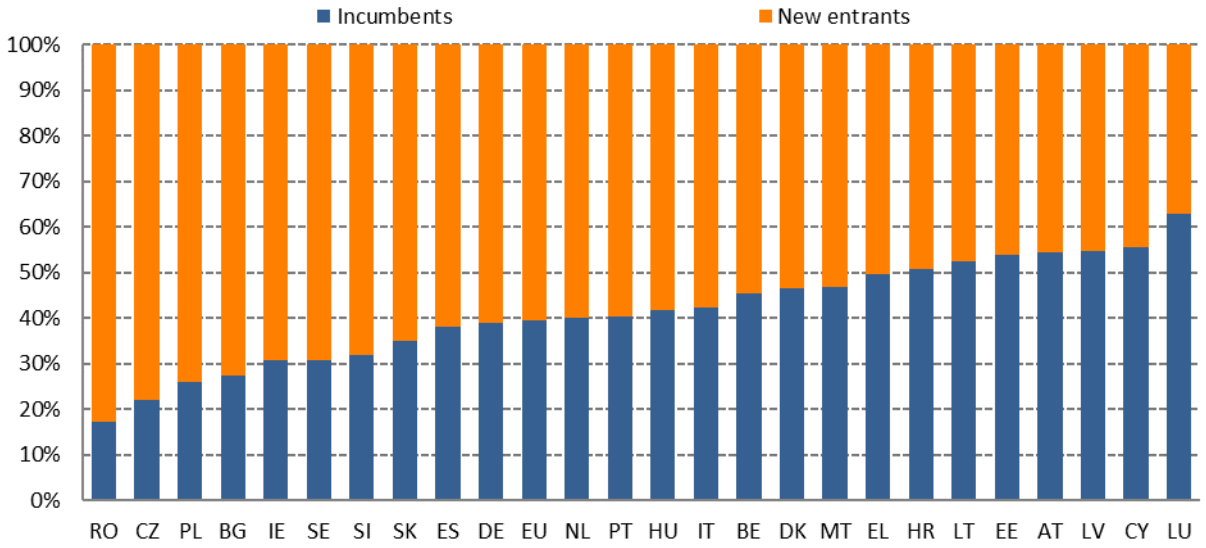
Source: Communications Committee (COCOM).

Figure 20 Incumbent operator market share by technology in the EU (% of subscriptions), July 2020



Source: Communications Committee (COCOM).

Figure 21 Fixed broadband subscriptions – operator market shares in the EU (% of subscriptions), July 2020

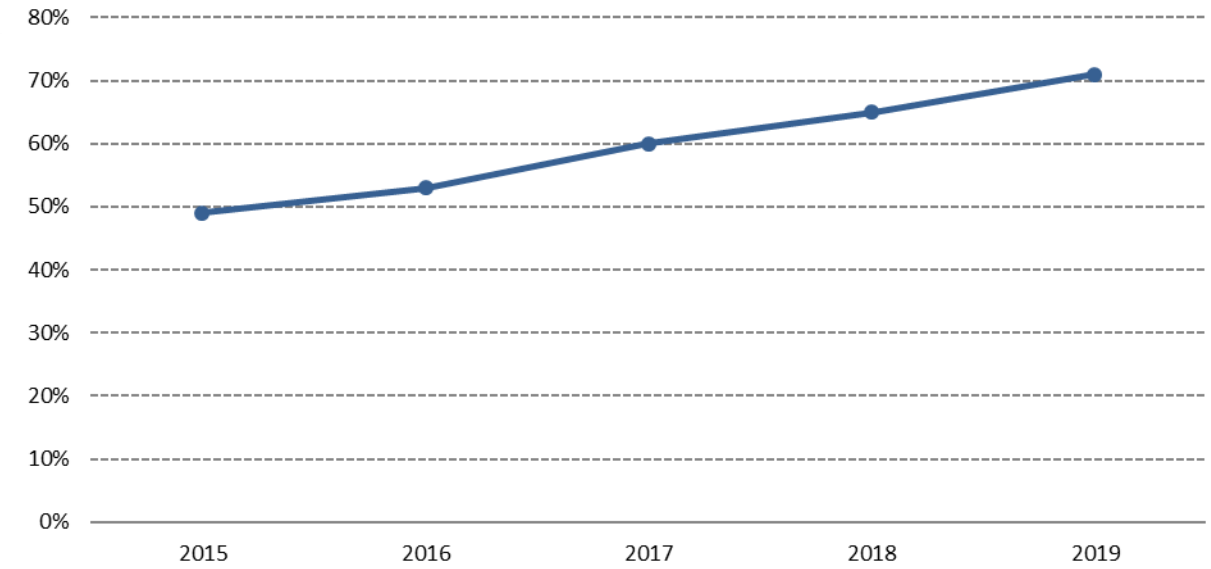


Source: Communications Committee (COCOM).

1.1.3 Mobile broadband take-up

In 2019, 71% of people used a smart phone to access the internet (up from 49% in 2015), which is the vast majority of all regular internet users (84% of people in 2019).

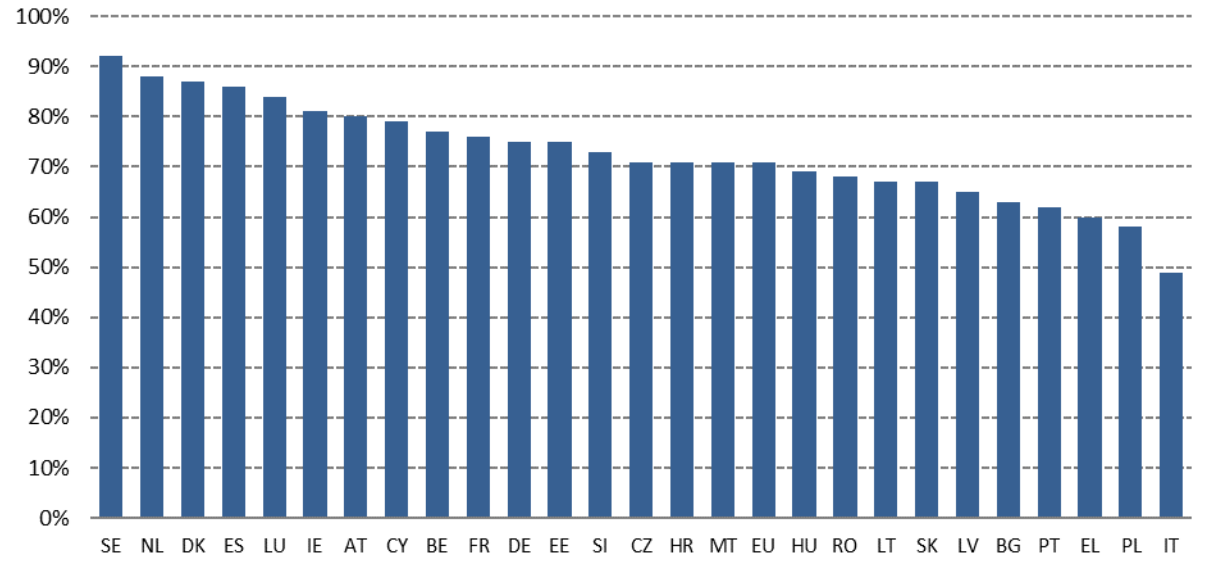
Figure 22 Mobile broadband penetration in the EU (% of individuals), 2015-2019[6]



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Mobile broadband is widely used in every Member State; national penetration rates vary between 49% in Italy and 92% in Sweden.

Figure 23 Mobile broadband penetration (% of individuals), 2019[7]

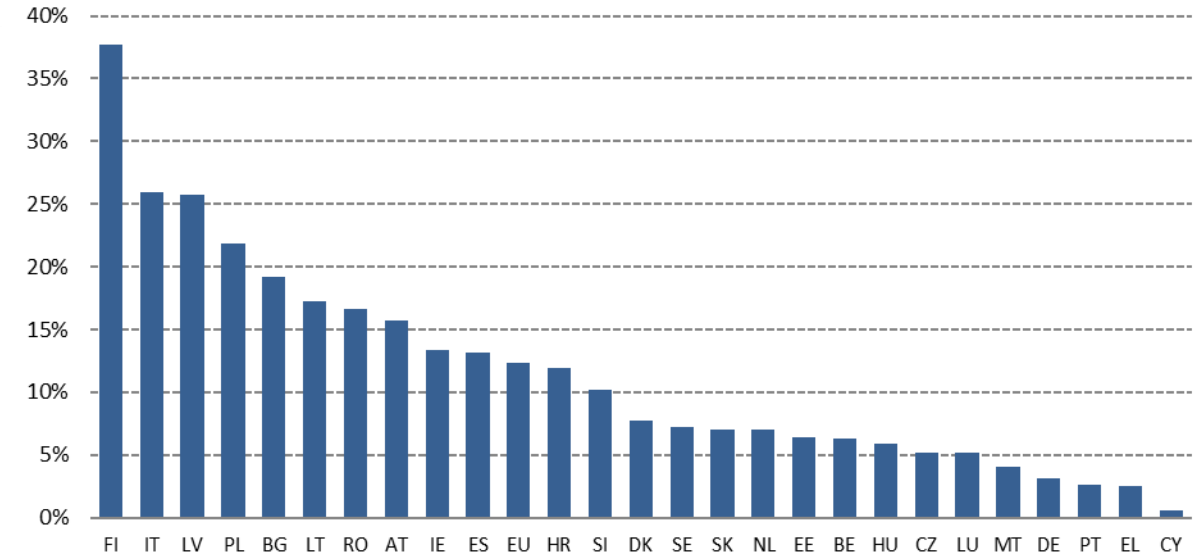


Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

Mobile broadband is, however, still mainly complementary to fixed broadband, when it comes to subscriptions for households. Europeans primarily use fixed technologies at home to access the internet (even if using a mobile device). In 2020, 12% of EU households accessed the internet only through mobile technologies. Finland (38% of households), Italy (26%) and Latvia (26%) were the leaders in mobile-only access.

[6] Data refers to individuals using a mobile phone to access the internet.
[7] Data refers to individuals using a mobile phone to access the internet.

Figure 24 Households using only mobile broadband at home (% of households), 2020



Source: Eurostat, European Union survey on ICT usage in Households and by Individuals.

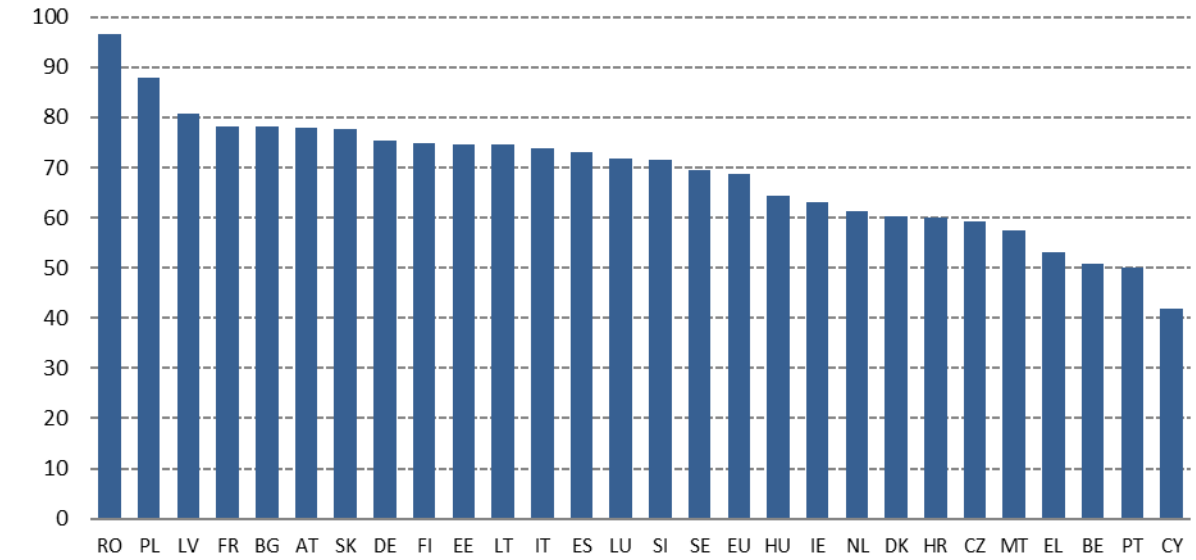
1.1.4 Broadband prices

The Broadband Price Index measures the prices of representative baskets of fixed, mobile and converged broadband offers.

The Broadband Price Index is a score[8] that measures the prices of over 30 representative broadband consumption baskets of different speeds and different products (standalone internet, double play, triple play and quadruple play).

Romania, Poland and Latvia have the lowest broadband prices, while Cyprus, Portugal and Belgium are the most expensive, when considering all fixed, mobile and converged baskets.

Figure 25 Broadband price index – all baskets (score 0-100, 100 meaning the lowest prices) 2020



Source: Commission, based on Empirica (Retail broadband prices studies).

[8] 0 to 100, 100 being the best.

1.1.5 EU support for National Broadband Plan (NBP) implementation

The Commission's strategies on Shaping Europe's digital future[9] and the Digital Decade[10] have confirmed the ambitious Gigabit objectives for fixed and mobile connectivity for all European citizens by 2025 and by 2030. As a recent study on NBP's[11] has identified, only few Member States are close to reaching the DAE targets, despite their ambitious NBPs. While Member states' NBPs differ significantly, all have an overall strategic approach for the deployment of NGA networks that is implemented in practice. There is a variety of conditions that influence the success of broadband roll-out. The NBPs of the Member States usually set one or two focal points out of the following spheres: demand side measures, supply side measures, regulatory and organizational measures and transparency measures. Successful NBPs consider their respective starting positions and describe concrete measures that take advantage of the individual strengths and define measures to mitigate the effect of disadvantages. In view of the new targets for 2025 and 2030, Member States should build on existing successful measures and orient their incentive towards the deployment and take-up of optical networks, which can be considered the most sustainable and future-proof solution in terms of exponentially growing data capacity usage. Incremental approaches to connectivity investments, such as 5G Fixed Wireless Access (FWA), can also be considered especially in remote areas, provided that the deployed infrastructures are scaleable and evolvable toward networks with fibre-based connectivity brought as close as possible to the users.

With at least 20% of expenditure dedicated to the digital transition, the Recovery and Resilience Facility (RRF) is an important opportunity for all Member States to invest in digital connectivity. Member States are planning to invest more than EUR 13bn (for 22 endorsed plans) into connectivity deployment, including for supporting the 5G roll-out, especially in rural areas.

In the 2014-2020 period, Member States had already used around EUR 6 billion of European Structural and Investment Funds (ESIFs) for broadband, the equivalent of 14.5 million additional households with access of at least 30 Mbps. Member States will have the possibility to access such support programmes also under in the next 2021-2027 ERDF funding period, especially for VHCN. Telecoms infrastructure projects have also been supported by European Fund for Strategic Investment (EFSI) guarantees and European Investment Bank (EIB) lending. As of 12 December 2019, approx. EUR 12.3 billion of estimated investments are mobilised thanks to a total EIB financing of EUR 3.47 billion, of which EUR 3.01 billion as a budgetary guarantee from EFSI. Under the 2021-2027 funding period, the InvestEU program continues to offer budgetary guarantees for investments in telecom infrastructure projects under its "Sustainable Infrastructure" Policy Window.

The Connecting Europe Broadband Fund (CEBF) launched in June 2018 has closed with an investment capital of EUR 555M in July 2021 and is expected to unlock total investments of between EUR 1.0 billion to 1.7 billion. The CEBF is investing in all EU Member States, as well as EEA Member States participating in the Telecom Connecting Europe Facility (Iceland and Norway). The project pipeline shows solid geographical diversification, as do the projects already signed by the Fund to date. Since its launch, the CEBF has successfully invested into 7 projects in Croatia, Slovenia, the UK, Spain, the Czech Republic, Italy and the Netherlands, respectively. The projects aims to deploy high-quality FTTH open-access networks for residential, business and public administration use and together aim to cover over 1.340.000 locations.

[9] https://ec.europa.eu/commission/presscorner/detail/en/ip_20_273

[10] https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/europes-digital-decade-digital-targets-2030_en

[11] Publication expected for October 2021.

The Commission continues to support in the 2021-2027 funding period the development of administrative capacity to design and implement NBPs through the Broadband Competence Offices Network first launched in 2017 (with currently 115 members). The network brings together national and regional authorities active in this field, and is supported by a permanent secretariat based in Brussels. The Commission provides also technical support through the Technical Support Instrument (TSI) for the Digital Transition, for example in order to enhance the efficiency and effectiveness of broadband investments and the implementation of the goals set for the Digital Decade by accelerating public investment in broadband.

Work to improve the mapping of broadband also continued with the review of existing national initiatives. According to Article 22 of Directive (EU) 2018/1972 (European Electronic Communications Code, EECC) all National Regulatory Authorities (NRAs) and/or Other Competent Authorities (OCAs) shall conduct a geographical survey of the reach of electronic communications networks capable of delivering broadband ('broadband networks') by 21 December 2023 and shall update it at least every three years thereafter. In addition, by early 2022, the revised Guidelines on State Aid for Electronic Communications networks will include mapping requirements for the purpose of the notification of state aid interventions

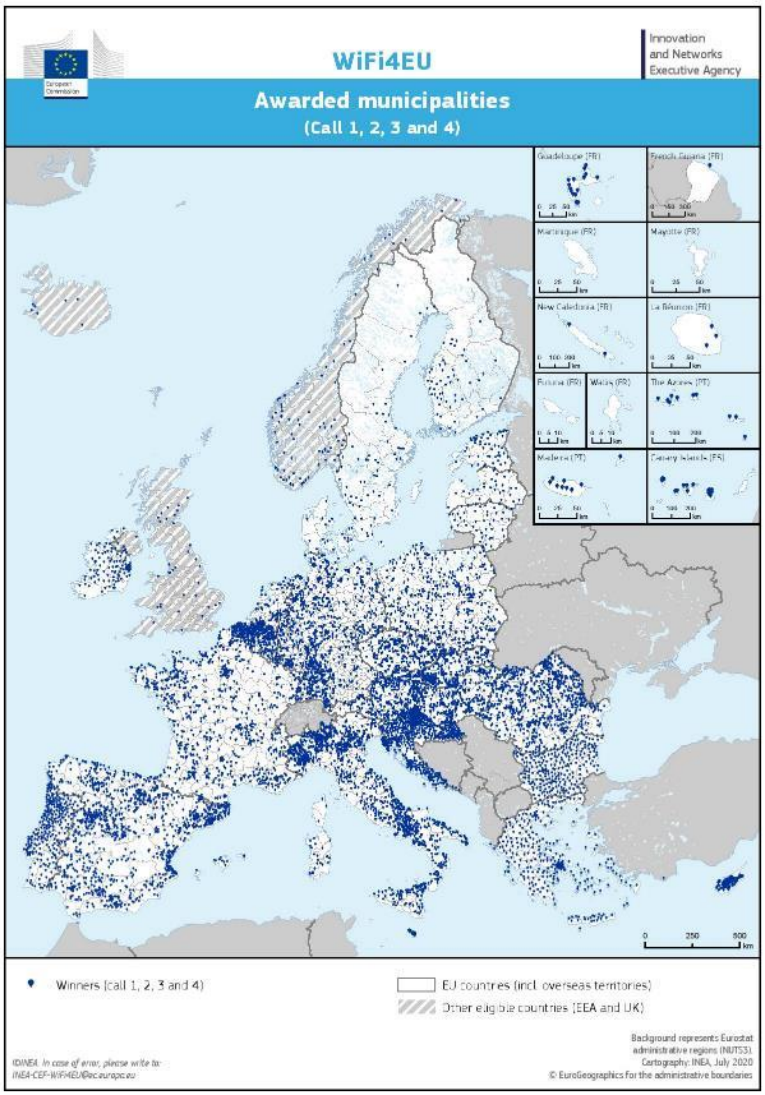
1.1.6 Municipalities need more connectivity – WiFi4EU

The WiFi4EU initiative continues to promote free Wi-Fi access in public spaces including schools, parks, squares, public buildings, libraries, health centres and museums in municipalities throughout Europe. With 4 WiFi4EU calls since November 2018, the initiative has by June 2020 awarded more than 8 800 vouchers to winning municipalities (Figure 42), i.e. around 30% of more than 29,000 municipalities that managed to register their interest.

Each voucher entitles the winning municipality to install a WiFi4EU network, and covers the costs with a fixed amount of EUR 15 000. The vouchers have been awarded on a first-come-first-served basis while ensuring geographical balance throughout the whole initiative. By July 2021 more than 4.700 out of 8800 municipalities had installed their networks, totalling more than 60.000 active access points, with peaks of more than 100.000 connected users per day. In order to mitigate the prolonged Covid-related challenges the deadlines for installing all funded networks has been extended to October 2022.

WiFI4EU represents a positive precedent of EU direct investment in local connectivity, which carries on under the next CEF2 Digital programme with a focus on 5G best practices. This new initiative also could provide blueprints for leveraging investments under other programmes, including Cohesion Funds, Agricultural funds and RRF.

Figure 26 WiFi4EU – Winning Municipalities by Country



Source: Innovation and Networks Executive Agency.

1.1.7 EU harmonised radio spectrum underpins future wireless digital services

The total EU harmonised radio spectrum for terrestrial systems capable of providing wireless broadband electronic communications services amounts to 4340 MHz, including the whole 26 GHz frequency band (24.25-27.5 GHz), while 2090 MHz thereof are subject to authorisation in accordance with the provisions of Directive (EU) 2018/1972 (European Electronic Communications Code, EECC). Under Decision (EU) 2017/899, the deadline for allowing the use of the 700 MHz frequency band (694-790 MHz) and in particular of the frequency division duplex part (703-733 MHz and 758-788 MHz) was 30 June 2020 [12]. In addition, pursuant to Article 54 of the EECC , the deadline for allowing the use of the 3.6 GHz frequency band (3400-3800 MHz) and at least 1 GHz of the 26 GHz frequency band (subject to market demand), was 31 December 2020.

At 31 August 2021, 56% of the EU harmonised radio spectrum for wireless broadband had been awarded across Member States. In particular with relation to the 5G pioneer spectrum, almost half a year after the expiry of the deadline in Article 54 of the EECC, and while some Member States had

[12] Decision (EU) 2017/899 of the European Parliament and of the Council of 17 May 2017 on the use of the 470-790 MHz frequency band in the Union (OJ L.138 of 25.05.2017, p.131).

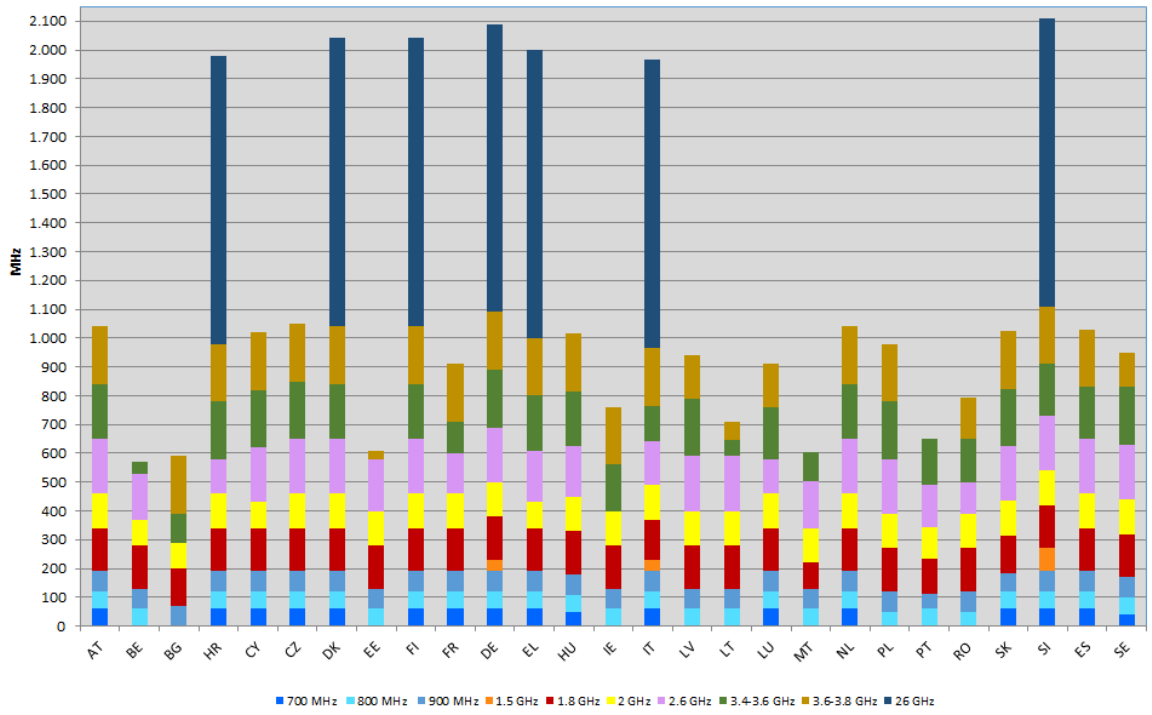
announced the postponement of spectrum awards due to the COVID-19 crisis or are still in the process of resolving other issues (e.g. pending cross-border coordination), seventeen (17) Member States have assigned the 700 MHz band (two not in full), twenty four (24) Member States have assigned (totally or partially) the 3.6 GHz band, while the 26 GHz band (≥1GHz) has been assigned only by seven (7) Member States. New spectrum auctions of 5G pioneer spectrum are expected by end 2022 or later.

Taking into account the above timeframes as well as the information gathered by the Commission, with relation to the administrative measures taken so far by Member States towards the fulfilment of the above obligations, there is some concern about the delays in the implementation of EU law regarding the authorisation of radio spectrum for 5G.

Current delays may be due to different reasons depending on the circumstances in each Member State, such as cross-border coordination issues or use of radio spectrum for defence purposes. In this context, and given the different regulatory conditions applicable to each band, lack of assignment does not necessarily mean non-compliance with EU law.

Denmark, Slovenia, Bulgaria, Spain, Sweden and Croatia completed the latest auctions in 2021. The Danish auction assigned spectrum in the 1400 MHz (90 MHz), 2100 MHz, 2300 MHz, 3.6 GHz and 26 GHz (2.85 GHz) bands. The Slovenian auction assigned spectrum in the 700 MHz (60 MHz of FDD part and 15 MHz of SDL part), 1400 MHz (80 MHz), 2100 MHz, 2300 MHz (70 MHz), 3.6 GHz (380 MHz) and the 26 GHz (1 GHz) bands. The Bulgarian auction assigned the 3.6 GHz (300 MHz) band, the Spanish auction assigned the remaining part of the 3.4-3.6 GHz (20 MHz) band followed by the 700 MHz (60 MHz) band, the Swedish auction ended up with the assignment of the 3.6 GHz (320 MHz) along with the 2300 MHz (80 MHz) band, and lastly the Croatian auction assigned all the three 5G pioneer bands.

Figure 27 Assigned radio spectrum for wireless broadband in harmonised EU bands, 31 August 2021



Source: European Commission

1.1.8 Convergent radio spectrum management approaches are essential to support 5G investment

700 MHz band (60 MHz):

Assigned in fifteen (17) Member States (AT, HR, CY, CZ, DE, DK, FI, FR, EL, IT[13], HU, LU, NL, SK, SI, ES, SE) so far, while other countries are expected to authorise the band by end-2021. Currently, seven Member States (HR, CY, ITPL, EE, LV, LT) are still in the process of resolving cross border issues (with EU and/or non-EU countries) or freeing up the band from incumbent users, which is causing delays in allowing the use of the 700 MHz band wireless broadband. On average, 61.1% of this band has been assigned in the Union.

This band has generated lower sale prices than the 800 MHz band in most Member States (except for France, where four mobile network operators were competing, and Sweden, where only 40 MHz of radio spectrum out of a total of 60 MHz were made available). Initial licenses last slightly longer than those for the 800 MHz band, with an average of 18.1 years.

3.6 GHz band:

Assigned (at least partially) in twenty four (24) Member States under '5G conditions' in accordance with Commission Implementing Decision (EU) 2019/235 of 24 January 2019. Denmark, Bulgaria, Slovenia, Croatia and Sweden were the latest Member States to assign spectrum in the 3.6 GHz band, boosting the average volume of assigned spectrum in this band to 70.9% in the Union.

26 GHz band:

So far awarded, for 5G use, only in Croatia, Italy, Finland, Greece, Slovenia and Denmark, while Germany has started, as of Q4 2020, assigning spectrum within the whole 26 GHz band on a first come, first served basis. This makes them the seven Member States in the Union to have assigned all the 5G pioneer bands. On average, 25.9% of this band (when considering the harmonized portion thereof) has been assigned in the Union.

The 800 MHz band (the 'digital dividend I') is currently assigned in all Member States (in two cases only partially) except for Bulgaria, which has been exempted due to incumbent military use under Article 1(3) of the Radio Spectrum Policy Programme.

Implementing Decisions

Since 2018, the Commission has adopted the following Decisions, pertinent to wireless broadband:

- Commission Implementing Decision (EU) 2018/661 (amending Decision (EU) 2015/750) as regards the extension of the 1.5 GHz band to provide 50 MHz of additional download capacity for 5G services.
- Commission Implementing Decision (EU) 2019/235 (amending Decision 2008/411/EC) to update the relevant technical conditions applicable to the 3.6 GHz band to make the band 5G-ready as it has been identified as the primary pioneer band for 5G in the EU.
- Commission Implementing Decision (EU) 2019/784 to harmonise the technical conditions applicable to the 26 GHz band. This band will be essential for some of the envisaged 5G use cases such as enhanced mobile broadband, specific vertical services that require short response times and extremely high data rates and fixed wireless access for the provision of

[13] The 700 MHz frequency band will be available for use in Italy from July 2022 as the authorities have obtained an exception as provided for in Decision of the European Parliament and the Council on the use of the 470-790 MHz band in the Union.

high-speed internet to households and businesses in areas with limited availability of fixed broadband technology.

Moreover, the Commission further delivered on its 5G spectrum roadmap by recently adopting three Decisions regarding the 26 GHz, the paired terrestrial 2 GHz and the 2.6 GHz frequency bands:

- Commission Implementing Decision (EU) 2020/590 of 24 April 2020 amending the harmonised technical conditions of Decision (EU) 2019/784 for use of the 26 GHz band, taking due account of the international agreement reached at the last World Radiocommunication Conference in 2019. It adapts the technical conditions for the protection of the passive satellite services below 24 GHz, which are used for earth monitoring and climate observation (e.g. for the European Copernicus programme). This amendment strikes a sensitive balance in promoting Union policies on 5G deployment and climate change.
- Commission Implementing Decision (EU) 2020/667 of 6 May 2020 amending the harmonised technical conditions of Decision 2012/688/EC, in order to make the paired terrestrial 2 GHz band fit for 5G use, under the principle of technology neutrality.
- Commission Implementing Decision (EU) 2020/636 of 8 May 2020 amending the harmonised technical conditions of Decision 2008/477/EC, in order to make the 2.6 GHz band fit for 5G use, under the principle of technology neutrality.

It is an established EU policy, enshrined also in the European Electronic Communications Code, that authorisation conditions conducive to investment in 5G deployment should avoid extracting excessive capital from the market and should promote ambitious infrastructure roll-out targets (including along rail and roads). The conditions should also enable innovative services, create opportunities for vertical services to access radio spectrum and not artificially limit or apportion radio spectrum supply, in particular in the 3.6 GHz band where large blocks of contiguous spectrum should be made available to operators to unleash the full 5G potential.

In the same context, Member States are now in the process of implementing the common Union Toolbox for Connectivity, which was adopted end of March 2021, in response to the Commission Connectivity Recommendation 2020/1307 of September 2020. The Connectivity Toolbox is comprised of a common set of 39 best practices that will foster digital network deployment and facilitate access to 5G spectrum. With regard to radio spectrum, the Toolbox includes best practices on conditions conducive to investments, incentivising 5G network rollout and reinforcing coordination of radio spectrum assignment for 5G across borders vertical applications. It also touches upon aspects related to electromagnetic fields and public health. Member States shall report on the progress of the implementation of the toolbox, according to their national roadmap, by end of April 2022.

1.1.9 Ex ante market regulation: state of play

With the exception of the termination markets, *ex ante* market regulation is largely concentrated in the broadband markets.

Nevertheless, *ex ante* market regulation is still maintained in a few Member States for certain markets included in the 2003, 2007 and the 2014 recommendations on relevant markets.

Figure 28 Article 32 cases as at 1 July 2021

Effective competition - no ex ante regulation
No effective competition - ex ante regulation
Partial competition - partial ex ante regulation

n number of rounds of market analysis

	2020 RECOMMENDATION		2014 RECOMMENDATION			2007 REC.		2003 RECOMMENDATION								
	Wholesale local access	Wholesale dedicated capacity	Call term. on fixed network	Voice call term. on mobile networks	Wholesale central access	Access to PSTN for res & non-res.	Call orig. on fixed network	Local/nat. Call for res.	Internat. call for res.	Local/nat. call for non-res.	Internat. call for non-res.	Retail LL	Transit on fixed network	Trunk segments LL	Access & call orig. on mobile network	Broadcast Transmis.
	Market 1	Market 2	ex-Mkt 1	ex-Mkt 2	ex-Market 3b	ex-Mkt 1	ex-Mkt 2	ex-Mkt 3	ex-Mkt 4	ex-Mkt 5	ex-Mkt 6	ex-Mkt 7	ex-Mkt 10	ex-Mkt 14	ex-Mkt 15	ex-Mkt 18
Austria	5	5	3	4	5	4	4	3	2	4	3	4	1	2	1	4
Belgium	3	2	3	3	3	3	2	3	1	3	1	2	2	1	1	2
Bulgaria	3	2	4	4	2	3	3	2	2	2	2	1	1	1		
Croatia	2	3	2	2	2	2	2	1		1		1		3		
Cyprus	4	3	3	4	4	3	3	3	2	3	2	2	3	3	4	4
Czech Republic	3	3	5	5	3	4	4	2	2	2	1	2	1	1	2	2
Denmark	4	4	4	5	4	4	4	2	2	1	1	2	1	1	1	1
Estonia	4	3	4	5	4	3	3	1	1	1	1	1	1	2	1	3
Finland	4	1	2	1	4	2	3	2	1	2	1	2	2	1	1	3
France	6	4	5	5	6	4	4	1	1	1	1	2	1	3	1	4
Germany	5	2	5	6	5	4	4	2	1	2	1	2	2	1	1	5
Greece	4	3	4	4	4	3	3	3	1	3	1	3	3	3	1	1
Hungary	4	4	4	6	4	6	4	3	3	3	3	3	2	2	2	3
Ireland	3	3	5	3	3	3	3	2	2	2	2	2	2	2	1	3
Italy	4	4	3	6	4	3	2	2	2	2	2	2	3	2	2	2
Latvia	4	4	5	5	4	2	3	4	3	4	3	3	2	1	1	1
Lithuania	4	2	5	4	4	2	3	3	2	3	2	2	2	2	1	6
Luxemburg	3	3	4	6	3	3	3	2	2	2	2	2	1	2	1	
Malta	2	3	4	4	2	3	3	2	2	2	2	3	2	2	2	1
Netherlands	5	3	5	5	4	4	3	2	2	2	2	2	2	2	1	2
Poland	3	3	3	3	4	3	4	2	2	2	2	2	1	2	2	3
Portugal	3	3	3	3	3	2	2	2	2	2	2	1	1	3		2
Romania	4	2	3	3	3	2	2	1	1	1	1		3			2
Slovakia	3	4	5	6	3	4	4	2	2	2	2	2	2	1	1	2
Slovenia	4	3	2	5	4	3	3	2	1	1	1	2	3	1	3	3
Spain	4	3	4	4	4	4	3	2	2	2	2	2	2	4	2	4
Sweden	3	3	5	5	4	3	3	1	1	1	1	2	2	1	1	5

Source: European Commission

1.1.10 Open internet rules

Under Regulation (EU) 2015/2120 (the Open Internet Regulation), EU citizens are entitled to distribute and have access to information and content, to use and provide applications and services, and use terminal equipment of their choice, regardless of the location of the end user or provider or the location of the information, content, application or service. These rights are established by the EU Regulation, which is directly applicable and binding in its entirety.

Applicable since 2016, this Regulation is a major achievement for Europe's Digital Strategy. Common EU rules on open internet access ensure that the same provisions apply across Europe. The enforcement of the open Internet access rules is an important task of National Regulatory Authorities (NRAs), which should take utmost account of the reviewed guidelines[14] on the Implementation of the Open Internet Access Regulation, adopted by the Body of European Regulators for Electronic Communications (BEREC) in June 2020 and amending the guidelines of 30 August 2016. The Commission continues to monitor closely the application of the Regulation.

Regulatory developments

Following the introduction of confinement measures to fight the Coronavirus pandemic, the demand for Internet capacity increased, be it for teleworking, e-learning or entertainment purposes. The confinement measures highlighted the crucial role of digital technologies, allowing users to purchase essential goods and access services which would not otherwise be accessible[15]. To respond to this intensified flow of internet traffic, the Commission called upon the cooperation of major platforms, BEREC, telecom operators and the public to ensure connectivity and an open internet across Europe. Streaming platforms were advised to offer standard rather than high definition and to cooperate

[14] https://berec.europa.eu/eng/document_register/subject_matter/berec/regulatory_best_practices/guidelines/9277-berec-guidelines-on-the-implementation-of-the-open-internet-regulation

[15] Communication from the Commission to the European Parliament and the Council, New Consumer Agenda: Strengthening consumer resilience for sustainable recovery, COM(2020) 696 final, Chapter II, available here

with telecom operators. Telecom operators had to take preventive and mitigating measures. Users were invited to apply settings that reduce data consumption, including the use of Wi-Fi or lower resolution content[16].

As a precautionary measure, in March 2020, a joint statement of the Commission and the BEREC set up a Special Reporting Mechanism (SRM) to ensure regular monitoring of the internet traffic situation in each Member State, in order to respond swiftly to possible capacity issues that could follow from increased internet usage due to Covid-19 containment measures.

During the entire reporting period, 33 NRAs have shared their data about the impact of the crisis on electronic communications networks and the actions taken so far at national level. The SRM summarises the status of internet capacity and the actions taken by different NRAs. All iterations of the SRM published by BEREC are available on the BEREC website.

In general, three phases in the evolution of internet traffic have been observed during the crisis: a sharp increase in its early weeks, a subsequent stabilisation and, through the latter part of 2020 and into 2021, a decrease from the peak (experienced early in the crisis). NRAs are monitoring the situation and are collecting data from ISPs and other market players about the status of their networks.

Open internet annual reports

The Open Internet Regulation (Article 5 of Regulation (EU) 2015/2120) requires national regulatory authorities to publish annual reports on their monitoring and findings and to share these reports with the Commission and BEREC. The latest annual country reports (covering 1 May 2020 to 30 April 2021) are available here.

In addition, BEREC publishes an annual report on the implementation of the Open Internet Regulation and the net neutrality guidelines.

Open internet issues

Zero-rating offers were identified by twenty five NRAs, with music/video streaming and social networking the most frequently mentioned types of applications being zero-rated. During the pandemic, there were some examples of temporary zero-rating practices to facilitate education and ensure the flow of information in several Member States. Twenty seven NRAs came across traffic management practices in one or another way, as more and more NRAs have realised the importance of compliance with the Regulation in this area.

In 2020, NRAs pursued their analysis of individual commercial offers emerging on the market on a case-by-case basis. 10 NRAs (BG, CY, ES, FR, HR, IT, MT, NO, SE, SK) carried out formal assessments of traffic management practices.

With the view to implementing Article 4 on monitoring ISPs' compliance with transparency and contractual terms, most (24) NRAs had recourse to formal and informal requests for information from the ISPs, analysis of end-users' reports and complaints, as well as market surveys. Most of the NRAs (23 out of 28) monitor end-user complaints regarding the performance of the IAS, while two thirds of the NRAs (18 out of 28) offer an IAS quality monitoring mechanism to consumers. On 15 September 2020, the Court of Justice of the European Union (CJEU) interpreted for the first time

[16] Communication from the Commission to the European Parliament and the Council, New Consumer Agenda: Strengthening consumer resilience for sustainable recovery, COM(2020) 696 final, Chapter II, available at EUR-Lex - 52020DC0696 - EN - EUR-Lex (europa.eu)

Regulation 2015/2120[17]. In Joined Cases C-807/18 and C-39/19 Telenor Magyarország Zrt. v Nemzeti Média-és Hírközlési Hatóság Elnöke, the Court was asked to give a preliminary ruling in relation to the additional services offered by Telenor Magyarország Kft relating to social media (chat) applications and music streaming and online radio applications. The Court ruled that this practice entails a traffic management measure which infringes the requirement of fair and non-discriminatory treatment laid down in Article 3(3) of Regulation 2015/2120. The Court also clarified that once that infringement has been established under Article 3(3) of Regulation 2015/2120 concerning traffic management, it is no longer necessary to specify whether there has also been an infringement of Article 3(2) of Regulation 2015/2120 about commercial agreements. Therefore a detailed assessment of the market and the impact of the measure is not needed.

1.1.11 Widespread use of roam-like-at-Home (RLAH) & multiplication of roaming traffic under RLAH

As of 15 June 2017, mobile operators are not allowed to impose charges other than domestic ones when they provide (retail) roaming services to customers periodically travelling in the EU/EEA. There are two main exceptions to this "Roam-like-at-home" (RLAH) rule. To prevent abusive or anomalous use of roaming at domestic prices, mobile operators may apply a fair use policy. Furthermore, when mobile operators are able to demonstrate that RLAH is objectively not sustainable without detrimental effects on the domestic markets, they may obtain an authorisation from their national regulator to impose a small surcharge for providing roaming services (sustainability derogation surcharge).

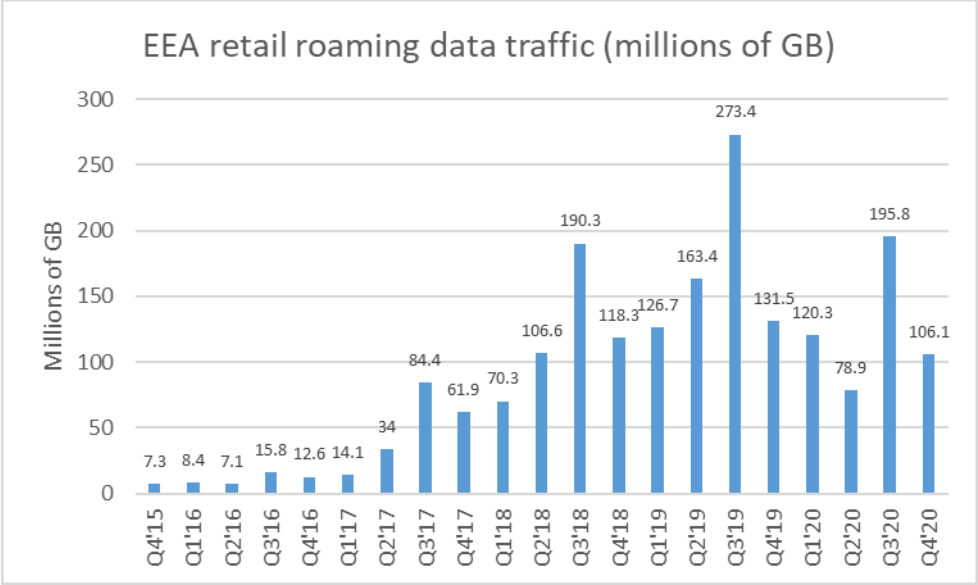
Roaming traffic

The rapid and massive increase in roaming traffic since June 2017 (Figure 45) has shown that the RLAH reform has met its objective to unleash the untapped demand for mobile consumption by travellers in the EU, as assessed in the Commission review report[18]. Between summer 2016 and summer 2019, retail roaming traffic increased 3-fold for voice and 17-fold for data. Between summer 2018 and summer 2019, roaming traffic remained stable for voice, while it increased further, by more than 40%, for data. Despite such increases, roaming traffic remains a small fraction of domestic traffic. Overall, consumers are highly satisfied with their higher roaming consumption and the benefits they derive from it.

[17] https://curia.europa.eu/juris/liste.jsf?num=C-807/18

[18] Commission Report on the review of the roaming market, COM(2019)616 final and accompanying Commission staff working document SWD(2019)416 final, both available here.

Figure 29 EEA retail roaming data traffic (millions GB)



Source: Based on the 27th BEREC Benchmark Data Report, April 2020-September 2020[19]. Please note that EEA average includes United Kingdom operators' data only until Q3 2019.

As an effect of the COVID-19 pandemic and the lockdowns and limitations to travelling, the roaming data traffic has decreased by almost 39% in 2020 compared to 2019. In particular, although some restrictions were lifted during the summer of 2020, the reduction of roaming data traffic amounted to -28% compared to the summer of 2019. In addition, part of the decrease is also a consequence of the fact that due to Brexit UK operators' data are not included in the reported roaming traffic since Q3 2019. RLAH rules no longer apply to the UK after the end of the transition period (*i.e.* after 31 December 2020). This means that roaming traffic in the United Kingdom should be treated like any other roaming traffic to countries outside the EU. EU-based operators are not obliged to offer calls, SMS or data services at domestic prices when their customers travel in the United Kingdom.

Fair use policies and sustainability derogations served their purpose in ensuring the sustainability of the RLAH regime, although their use remains marginal. In summer 2019, voice or data roaming traffic subject to a surcharge due to a fair use policy or a sustainability derogation did not exceed 6% of total roaming traffic in the EU. Apart from mobile virtual network operators, derogations are mainly used in some countries where data prices are very low, revenues per user are low and/or roaming imbalances are high (e.g. Estonia, Finland, Lithuania and Poland).

Roaming issues

Overall, mobile operators are complying with the roaming rules. However, certain issues were observed.

For instance in the Netherlands, the NRA noted problems with quality of service in roaming where the roaming provider (home operator) blocks access to 4G roaming, only enabling 3G access or limiting the available data speed on certain visited networks. The NRA did not take any formal steps due to lack of legal clarity regarding quality of roaming services.

Furthermore, in the context of the review of the EU Roaming Regulation, the Joint Research Centre (JRC) undertook a study (Smart 2018/0011) on roaming performance assessment by field measurements on mobile broadband involving 40 mobile networks in 13 EU countries. JRC's mobile

[19] International Roaming BEREC benchmark data report April 2020 - September 2020, available here.

app netBravo was used to carry out the measurements and analysis of data. Download speed, upload speed and latency were measured for all roaming tests and results were analysed. The study found that 25% of customers at least once had worse quality of service in roaming compared to at home even when technical conditions were available for better quality.

Regulatory developments

The Roaming Regulation will expire on 30 June 2022. In this light, the Commission has adopted a RECAST proposal on 24 February 2021 for extending the Roaming Regulation for 10 years to ensure continuation of 'roam like at home' and maintain its benefits for consumers beyond 2022, as well as ensure a genuine roam like at home experience and facilitate innovation. In addition to the prolongation for 10 years of the existing roaming rules and the reduction of wholesale caps to ensure sustainability of roam like at home for operators, the Commission proposed the following new measures; (i) same quality of services while roaming as at home, (ii) increased transparency to avoid bill-shocks for consumers from using value added services, (iii) equivalent access to emergency services for all, and (iv) wholesale roaming access to requested network technologies.

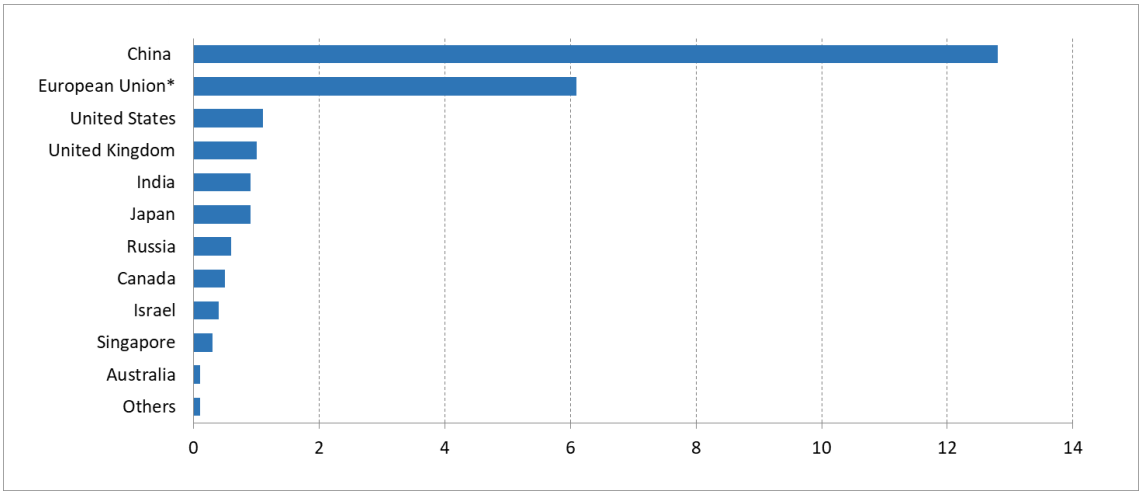
1.2 Quantum computing

Quantum technologies exploit the properties of quantum mechanics and physics to solve complex problems much faster or much better than traditional methods. They make possible the development of radically new technologies in computing, communication, simulation, and sensing. Quantum computing can be applied in many sectors (aerospace, agriculture, health, automotive or energy) and in combination with other digital technologies. For example, quantum cryptography techniques can help develop secure communications and improve detection of network intrusions. In addition, quantum technologies can help improve the ICT performance by for example, increasing energy-efficiency of computing and sensing or the capability to store and analyse growing amounts of data[20].

A great deal of investment and expertise will be needed to help quantum technologies transition from the research and development phase to deployment. Currently, they still rely largely on public funds, and most of fundamental research is done in universities and research facilities. Equity funding is still low for quantum computing compared to other emerging technologies. China, the EU, the US, the UK, India, and Japan are investing strongly in quantum technologies.

Figure 30 Planned public funding in quantum technologies, examples worldwide, in EUR billion

[20] JRC, *Quantum Technologies: Implications for European Policy, Issues for debate,* 2016



Source: CIFAR, A quantum revolution: report on global policies for quantum technology, April 2021.

**Includes planned public funding by the EU and Member States.*

The EU objective in the Digital Decade for quantum is that by 2025, Europe will have its first computer with quantum acceleration paving the way for Europe to be at the cutting edge of quantum capabilities by 2030[21].

In October 2018, the EU launched the ten-year strategic Quantum Technologies Flagship with an expected budget of EUR 1 billion. This large-scale initiative will pool resources of research institutions, industry and public funders to consolidate and expand European scientific leadership and excellence in this field. In its ramp-up phase (from October 2018 to September 2021), it provided EUR 152 million of funding for 24 projects in four core application areas: quantum communication, computing, simulation, and sensing and metrology. In the up-coming research framework programme Horizon Europe (2021-2027) the European Quantum Flagship Initiative will become fully operational with a total investment of EUR 1 billion. In March 2020, the European Quantum Flagship Initiative presented its Strategic Research Agenda[(22)] setting ambitious goals around the four core application areas. These areas are anchored by a common basis in basic science and they will be supported by work in cross-cutting areas (engineering and control, software and theory, education and training), and further complemented by overarching activities in innovation and international cooperation as well as gender equality.

In June 2019, the European Commission and several Member States signed a ministerial declaration agreeing to explore together, over a period of 12 months, how to develop and deploy a quantum communication infrastructure (QCI) across the EU within the next 10 years[(23)]. In the next multiannual financial framework for the period 2021-2027, the EuroHPC Joint Undertaking (JU) will support at least two generations of widely accessible quantum computers and advanced simulators interconnected with EuroHPC supercomputing facilities as part of a federated European computing infrastructure.

[21] COM(2021) 118 final, 2030 Digital Compass: the European way for the Digital Decade, 9 March 2021.

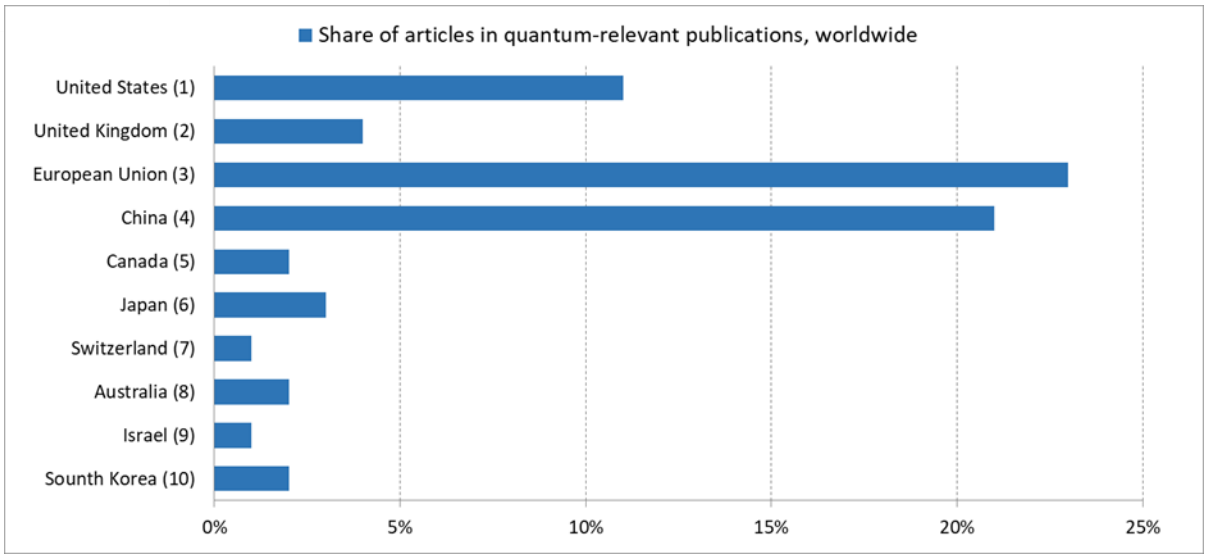
[22] https://qt.eu/about-quantum-flagship/newsroom/the-quantum-flagship-officially-presents-the-strategic-research-agenda-to-the-european-commission/

[23] https://digital-strategy.ec.europa.eu/en/news/future-quantum-eu-countries-plan-ultra-secure-communication-network

As regards the share of articles in quantum-relevant publications in 2020, the EU was the most active, followed by China and the US. However, in terms of impact[24] the US had a leading position in quantum-relevant publications, followed by the UK, the EU and China.

[24] H index evaluates the impact of the scientific publications by measuring the number of articles (h) in a country that received at least h citations.

Figure 31 Top 10 countries worldwide by H index in quantum-relevant publications, 2020



Source: Scopus analyzer, keyword (quantum tecnolog).*

Patenting activity in the field of quantum computing started to accelerate in 2012. Quantum computing and quantum key distribution are the applications for which by far the most patent applications have been filed to date. The US leads in quantum computing and China leads in quantum key distribution[25]. Likewise, quantum metrology and sensing saw an increase in patent applications starting in 2009, but the number of patent applications is still low in absolute terms, and mainly driven by research institutes (patent applications in the field rose from 8 applications in 2009 to 83 in 2017). The leading patent authorities in this sub-sector are China, the US and the EU[26]. Even though commercial products based on quantum-computing are starting to emerge (for example in quantum sensing), the market for quantum technologies still appears to be limited.

Revenues from quantum computing market worldwide are expected to be €10 to €89 billion in 2040[27]. This preliminary market estimate includes revenues generated directly by quantum companies. It does not reflect the much broader, overall revenue impact the technology will have across the industries that use it.

[25] JRC, *Patent analysis of selected quantum technologies*, 2019.
[26] European Patent Office, *Landscape study on patent filling, quantum metrology and sensing,* 2019.
[27] Preliminary result of the final assessment report: Financing a quantum technologies industry in Europe, EIB/McKinsey, September 2021.